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PREFACE.

The object of this little book is to simplify the study of medicine for the beginner, and to connect the various subdivisions of this science in the minds of the busy practitioner in a rational and readily comprehended manner. There are, it seems almost needless to say, many who do not require this aid, and for such it is not intended, but it is offered to those who may find it useful. Its inception was the crystallizing experience of lecture room, dissecting room, and private teaching of students more than fifteen years ago. The plan followed in these pages is the same as that which in the past gave many a backward student a new impetus upon the highway of medical learning, as evidenced by his readier understanding of his lessons, and his improved standing in quizzes and periodic review examinations.

The aim is to stimulate study upon philosophic lines—to encourage the reasoning faculties. Facts are treated as of the first importance, and certain principles underlying these as second in value, while the reader is encouraged to so apply known principles to facts as to lead to true inductions by a route that is at once easy and pleasant. Medicine is a philosophic study and should be taught as such. It is a connected whole, and not, as the student and many practitioners so commonly imagine, a series of separate entities because of the numerous sub-divisions into departments and specialties.

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The true, or ideal, physician is the one to whom all parts of the body clearly reveal their harmonious similarity under all conditions, whether of health or disease. This is not intended, however, as an objection to specialism, but against the kind of specialism which entails real ignorance of those parts and functions of the body not directly connected with the special branch that is practiced. The best specialists are a gradual product, and are evolved from the successful general practitioner. These form the pioneer advance guard of medical progress, and are essential to the quickest development of medical art. But the function of the general practitioner is hardly secondary to that of the specialist even from this standpoint, for he correlates, connects. It is he who takes up the many separate threads and weaves them into the substantial and enduring fabric.

A true knowledge of the body requires, first of all, familiarity with all its parts, even to its minutest sub-divisions. This constitutes anatomy inclusive of histology—the study of structure. This information is of limited value without a knowledge of the functions of all these parts, and their relations to one another as a whole. This constitutes physiology—the study of function. Anatomy and physiology give us the normal, and familiarity with the normal structure and functions of the body enables us to detect deviations therefrom; tells us when the individual is ill at ease, dis—eased. To identify and classify the trouble involves an understanding of changed function under altered conditions, of modified action and structure. These are morbid, or abnormal, conditions, change of structure, perversion of function. This constitutes pathology—the study of abnormal anatomy and physiology.

A full understanding of these three, therefore, in their broadest sense, namely, anatomy, physiology, and pathology, make the diagonsis of disease and its rational understanding possible, thus indicating with precision the effects required of the remedies that are to be applied.

For the intelligent and efficient treatment of disease, it is necessary to know the various remedial agents and measures, together with their effect upon structure and function in health and disease. This constitutes materia medica and therapeutics—the study of remedies and their effects upon the structure and functions of the body, both normal and abnormal.

These, then, may be called the major divisions of medicine; anatomy and physiology, to enable us to detect deviations from the normal (disease); pathology, to specify the deviation (diagnosis); and materia medica and therapeutics, to rationally and effectively treat disease in accordance with what is known of its behavior.

The illustrations are almost all original and diagramatic, the former with a view to avoiding marked connection with any given text-book, and the latter so as to impress a principle upon the reader's mind rather than a set picture which he never sees for the reason that it does not exist.

It was finally decided, in consequence of the predominance of the histologic feature in these pages, to append a chapter upon the use of the microscope, giving such hints as would enable readers requiring the information to better understand the mechanism and use of the instrument.

A. H. P. LEUF.

2353 N. 17th St.

CHAPTER I.

THE CELL.

"Are we cell aggregates?" asked Montgomery, of Texas, in 1881, in Pfluger's Archive. There can be no doubt of it. The cells are connected, however, but not like so many bricks in a house. True, there is a "cement substance" between them, but this has only been studied in death. The union of some cells is more direct, for instance more like that of the leaves of a tree. Cells often are so many Siamese twins in their intimate organic connections. They have their individual being in one sense, while in another they have direct and indirect continuity. Their contents frequently intermingle through connecting bonds.

The Protameba.

The simplest form of life consists of an easily flowing, gelatinous like, mass called protoplasm in general, and known in its most independent form as the protameba.[1] It is one of the simplest forms of animal beings, having an irregular, constantly changing outline, and appearing uniformly homogeneous,[2] with large and small granular sprinklings under a glass of moderate power. It is a nitrogenous carbon compound of albumin, and often contains fat and sometimes mineral substances. It coagulates in death and at a comparatively slight elevation of temperature. It has the property of extending parts of itself in any direction to a sufficient extent to encircle other objects and draw itself completely around them. In this way it gets its nourishment, extracting from particles thus met in its path whatever is of advantage, and allowing the remainder to fall away from any part of itself where it happens to be nearest the surface; this is ingestion.[3]

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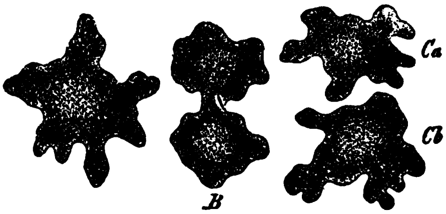
[1] From πρῶτος—first, and αμειβω—change.

[2] Meaning the same kind, from ὁμός—the same, and γένος—kind.

[3] From the Latin *ingerere, ingestum*—to place in, as into the stomach.

Following a universal law of nature, it seems evident that the protameba grows because it ingests, and such is the fact. It also gets rid of waste products and unassimilated material, and therefore egests,[4] from all of which it further follows, that it does work. Lastly, according to another law, it reproduces its kind. This is done in the simplest possible manner by parts separating from the original and growing to adult proportion, when they, in their turn, give birth to other protamebae. This simplest of all forms of animal life is found upon the surface of the seas.



The Protameba. **B, showing commencing division, and *Ca* and *Cb* the two parts after complete separation (Frey).**

The Ameba.

Another one of this class of bodies is found among the protamebae, but it is more active, contains a spheroidal structure, with granular contents, called a nucleus; and a larger amount of nutritive and alimentary contents, foreign unassimilable matter and air spaces or sacs. This is the ameba.[5] The protameba and the ameba, therefore, though the simplest forms of life, ingest, egest, work, grow and reproduce their own kind. This is the characteristic of all living matter, as we shall see in the following pages, and it is so because all living matter is composed of colonies and vast governments of amebae or their equivalents—cells. We ourselves are, therefore, nothing but vast complex collections of cells or modified amebae acting in concert as a connected whole.

The Cell.

The cell is the anatomical unit or element. It bears very much the same relation to our bodies that the molecule does to matter in physics. The material of which the ameba, or the jelly fish, is composed is called protoplasm.[6] A cell is a single modified protameba. How is it modified? By having a restricted environment. Limitation and what goes with it is as necessary to the cell as it would be fatal to the protameba or ameba. Frey says: "Thus this structure, which forms in an independent manner the body of the ameba, now constitutes our tissues, although in a very conditional independence." At one time cells were supposed to have cell walls, but Max Schultze showed that this existed only in old cells, and was evidence of a retrograde change, consisting in a hardening of the surface protoplasm. The latest researches, however, under very high power lenses, indicate that there is a true enveloping membrane around many, if not all, cells.

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[4] From the Latin *e*—out, and *gerere*—to place or carry.

[5] From *αμειβω*—change.

Cells vary in size from 0.076 to 0.057 mm. They may, therefore, be defined as minute pieces of protoplasm. Most of these pieces of protoplasm have within them a little chamber, or cavity, or body, called a nucleus.[7] Its average diameter is from 0.007 to 0.005 mm. The nucleus is not constant, and it is doubtful whether it is essential to all cells. Some kinds are never known to be without it. Brücke, Stricker and others showed that the nucleus was non-essential, basing their opinion upon the fact that non-nucleated cells are found in the cryptogamia[8] and some of the lowest animal forms. It is, however, hardier and more resisting to chemical agents than the cell protoplasm. It even happens that there often are two or more nuclei in one cell. In many instances, as we shall see later on, the nuclei have another nucleus within themselves, and this nucleus within a nucleus is called a nucleolus.[9]

Some cells have a homogeneous and transparent protoplasm, while in others it is very granular and opaque. Hyaline [10] cartilage is a good example of the former, and a nerve cell from the anterior horns of the spinal cord of the latter. A liver cell is intermediate between the two. Nerve cells are also the most constant in having nuclei and nucleoli. The protoplasm or body of some cells normally contains fat in certain proportions, as, for instance, those of the liver and those in the intestinal villi[11] during digestion.

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[6] The first or primary formation, from πρωτος—first, and πλασσω — I form.

[7] A nut or kernel; from the Latin *nux*, *nucis*—a nut.

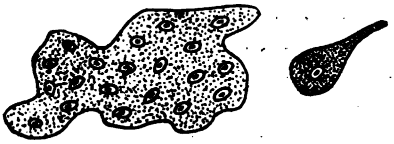
[8] From κρυπτός, concealed; γάμος, marriage; applying to plants having their sexual organs concealed.

[9] Diminutive of *nucleus*, meaning a little nucleus.

[10] Meaning glassy; from ὑαλος, or *hyalinus*—glass.

Cell Morphology.

In shape, or morphology,[12] as it is often called, cells differ widely. They may be flat and regular in outline; cylindric or columnar; fusiform or spindle shaped; chunky or irregularly cuboid; squamous or scale shaped; cup shaped; with hair like prolongations or ciliated; in short, they may have any form that would be suggested by pressure exerted in a number of ways, for the form of cells is largely due to pressure. It is a question of adaptation to environment or surrounding.



***Giant Cell*, showing it to be a large protoplasmic mass containing many nuclei.**

Giant Cells.

Giant cells are relatively large masses of protoplasm with many nuclei. They are found normally in the marrow of young bones. Hence they are also called myeloid[13] cells. They are also found in inflammatory and new growths.

Epithelial Cells.

The quality of cells is determined physiologically and anatomically. Epithelial[14] cells are such as cover open surfaces or surfaces communicating directly or indirectly with the air. They are found upon the integument and all mucous membranes. The various kinds of epithelium, as a rule, have morphologic and functional[15] differences. Their special functions are indicated by the site of the cells, and their shape by the common names already mentioned. For instance, we say columnar ciliated epithelium of the bronchial tubes. Thus we are told that these cells are epithelial, and that they are of the ciliated variety of columnar cells. We know their special function at once by being told that they are located in the bronchial tubes.

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[11] From the Latin *villus*—shaggy hair.

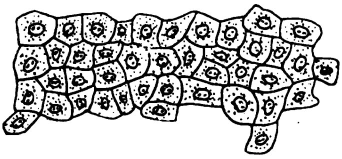
[12] From μορφη—form, and λογος—discourse; hence a discourse on form.

[13] From *myelo*—marrow, and ειδος—resemblance.

[14] From επ, εφ, επι—upon, and θηλη—nipple.

Endothelial Cells.

Endothelial[16] cells are found in all closed cavities and on membranes lining cavities that do not communicate with the skin or outer air. They are almost always of the tesselated[17] variety, so called because they fit edge to edge like tiles. As a rule, we find them in single layers. They line all the serous membranes, such as the pleurae, pericardium, peritoneum, arachnoid and the synovial sacs. They also line the interior of the blood and lymph vessels.



Tesselated Endothelium, from the peritoneum.

Endothelial Cells, from the posterior tibial artery of man (after Quain).

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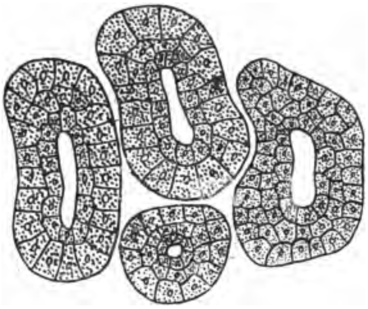
[15] From the Latin *Functis*—to perform or execute.

[16] From *ενδον*—within, and *θηλη*—nipple.

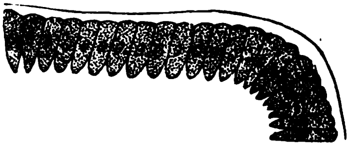
[17] From the Latin *tessella*—a small square piece.

Glandular Cells.

Glandular[18] or secreting epithelial[19] cells are so called because they secrete special juices of the body that are to serve some useful purpose. They are named glandular because they form the essential part of glands, and epithelial because they exist at the end of the ducts or canals that eventually communicate externally. They are called secreting because they furnish new products or juices that serve additional uses in the body. Hence they are epithelial, but of a secreting variety. Columnar cells belong also to the secreting variety.



Glandular Epithelium, **also called cuboid and secreting.**



Columnar Epithelium **(secreting), from an intestinal villus of a rabbit.**

Cell Shapes.

Squamous,[20] scale shaped, or pavement epithelium is found covering the skin, and the mucous membrane of the nose, mouth, pharynx, small ducts, conjunctivae, external ear canals, esophagus and genito-urinary tract.

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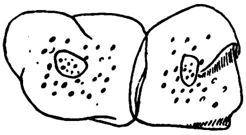
[18] From the Latin *glans*—an acorn. A name given to a series of ducts in which are arranged a mass of cells that form fluids to be used in the body.

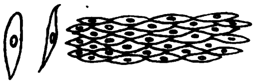
[19] From the Latin *secretum*—to separate.

[20] From the Latin *squama*—a scale.



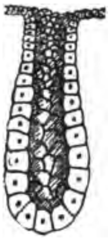
Squamous (pavement) *Epithelium.*

Fusiform[21] or spindle shaped epithelium is found in the upper layers of the skin and in the bladder.

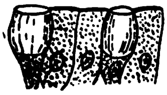


Fusiform (spindle-shaped) *Epithelium*, a diagramatic representation.

Chunky or irregularly cuboid epithelium, also called spheroidal and transitional,[22] is encountered in the bladder, ureters, kidneys, mammary ducts, perspiratory ducts, and the ducts of many mucous glands. Its modifications form glandular cells, which are found in glands and glandular structures.



Chunky (irregularly cuboid) *Epithelium*, being an ideal representation of a secreting follicle.



Cup-shaped Epithelium, from the human intestine.

Cup-shaped cells are found in the mucous membranes, and are generally supposed to be accidental, being caused by a swelling of the free end, by which is meant the portion between the nucleus and the free surface of the cell, while that upon the other side of the nucleus is thin and tapering.

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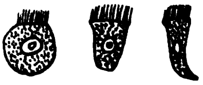
[21] From the Latin *fusis*—spindle, and *forma*—shape; tapering at both ends.

[22] So called because they are in a transition state from simple spheroidal cells to the columnar variety.

Ciliated Cells.

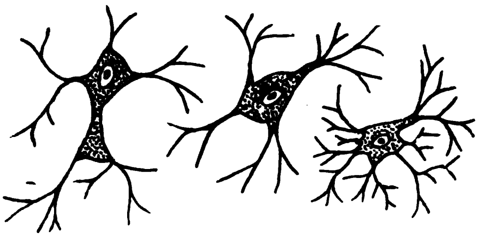
Ciliated[23] cells are generally of the columnar variety, and occur in but a few places. They are mainly found upon the mucous lining of the larynx, trachea, bronchi and the fallopian tubes. Their free surfaces are studded with numerous rapidly waving hair-like bodies, which are protoplasmic extensions from the cell. Their movement is so rapid that they cannot be separately identified while active. This very rapid motion is in marked contrast with all the other slow movements of protoplasm. The difference has not yet been explained. These ciliated cells are easily found in the mouth of the frog, scrapings from which, when viewed under the microscope, show the active living cilia.



Ciliated Epithelium, from a frog's mouth.

Connective Tissue Cells.

The connective tissue cell is irregular in shape, with numerous prolongations varying in length, and often united to



Connective Tissue Cells.

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[23] From the Latin *cilium*—an eyelash, which the cilia of cells closely resemble under the microscope.

similar processes from like cells. The mesh-work so formed serves as a support or frame work for the lodgment of the cells and nerves, ducts, blood vessels and lymphatics. These cells, as may be judged by their function, vary in size in different parts of the body, as do also their prolongations. They are larger or smaller as they are required to meet a greater or a lesser strain.

Lower Cells.

The cells so far briefly enumerated belong to what is called the lower type of cells. They have a relatively inferior function to perform, and are more general in their usefulness than those next to be considered. Those that have been mentioned have many common functions in all living beings and exist more or less in all parts of the body. Not having the high development of those to follow, they have a sturdier vitality under changed conditions.

Higher Cells.

The special or higher cells belong to particular parts of the body, and these are, for instance, those of the nervous system, liver, pancreas or muscles. Nowhere in the body but in the liver can a cell be found like a liver cell. No cell having the characteristics of a nerve cell can be discovered except in the nervous system. The same is true of all the other special cells. It is the sole duty of the liver cell to attend to liver digestion and the glycogenic function and the formation of bile. No other cell can do this. The nerve cell performs its feats of intelligence within its own proper sphere, and neither liver, kidney nor muscle cell could take its place. So it is of all the others. If a man had paralysis of his leg muscle and a piece of kidney was grafted between the ends of two

Liver Cells, from the human liver.

tendons, he could not work his foot any better than he could with the disabled muscle previous to the grafting. If a muscle is lost it is gone forever because it is composed of special cells.[24] The same is true of special cells generally. The lower cells are, however, replaced within certain limitations, as will be seen in succeeding chapters, and they exist almost everywhere.

Nerve Cells, from the inner part of the grey matter of the convolutions of the human brain.

Red Blood Cells.

The red cells, or corpuscles,[25] or erythrocytes,[26] of the blood are free and unrestricted by their fluid environment, the plasma.[27] Nevertheless, they are not known to have any motion such as the ameba. They always maintain their spherical contour with bi-concave sides. Apparently, they are merely passive agents in the exchange of oxygen and carbonic acid gas. The erythrocytes are easily caused to change their form while still alive under the microscope, the slighest pressure upon the cover glass sufficing to change their form and often partly fold them. Their great elasticity is shown by the quickness with which they assume their normal shape as soon as the pressure is removed.

The White Blood Cells.

The white cells or corpuscles, or leucocytes,[28] differ widely from their colored fellows in changing their outline in the same manner as the protameba and ameba. In passing through the capillaries,[29] the red cells keep moving quickly through the centre of the vessels, while the white corpuscles pass slowly along their walls, and occasionally they adhere and draw lazily along the wall in the direction of the current, and turn over their full length, repeating the process at intervals. When observed under a microscope on a warm slide, they slowly thrust out processes[30] or pseudopods[31] just like the ameba. A lymph corpuscle is so like the white cell of the blood that they cannot be told apart, and they are believed to be identical. The same similarity exists between these and the pus[32] cells. The leucocytes are present in the blood in the proportion of 1 to from 300 to 500 of the red.

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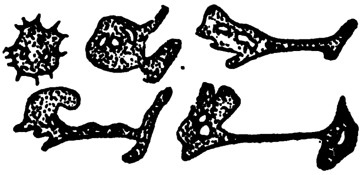
[24] In this connection it is interesting to note that, according to Wittich, a certain number of primary muscle fiber bundles of the frog are destroyed every winter and subsequently regenerated.

[25] Diminutive of the Latin *corpus*—a body.

[26] From *ἐρυθρός*—red, and *κυτός*—cell.

[27] From *πλασμα*—a thing formed. The fluid or non-corpuscular part of the blood; the *liquor sanguinis*.



Active Leukocytes, or white corpuscles ; the fine protoplasmic filament connecting the two main cell parts at last, gives way and two cells result.

Blood Plaques.

Within recent years, a great deal has come to light about what appears to be a third variety of blood cells. They are known by various names, but an able authority[33] has preferred to call them blood plaques.[34] They are also called

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[28] From λευκος—white, and κυτος—cell.

[29] From the Latin *capillus*—a hair, because they are so very fine.

[30] From the Latin *pro*—for, or before, and *cedere*—to move, go, or go along ; a jutting out.

[31] From ψευδης—false, and πους, ποδος—foot.

[32] Commonly called "matter."

[33] Professor William Osler, of Johns Hopkins University.

[34] Meaning "little plates." Also called globulinus, elementary corpuscles, granular debris, granule masses, blood plate, and third corpuscle. See Osler's interesting papers on this subject in the Med. Rec., April 3, 1886, and others that follow ; also Dr. Geo. T. Kemp's paper.

platelets, are believed to bear some relation to blood coagulation, and exist in the proportion of 1 to from 25 to 40 of the red cells. It appears to be the best name of all those offered. They are much smaller than either the red or white corpuscles of the blood, and have much the appearance of embryonic cells. Their action is not yet clearly understood.

Recent investigations, thanks to improved processes, have shown that cells as well as their nuclei are fully organized structures, consisting of a complex reticulum[35] containing a fluid or semi-fluid mass. Nuclei are elastic, being modified in shape by mechanic contact with less yielding substances, resuming their normal form when the modifying influence abates.

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[35] A little net, diminutive of rete—a net.

CHAPTER II.

TISSUES.

1. (Cell Compounds).

Tissues or textures[1] should properly include only the solids of the body, but custom has added such fluids as the blood and lymph to the list. The grouping of solids and liquids into one class is correct; but the name tissue is a misnomer, and one of our objectionable heirlooms from a too fanciful past. Tissues are continuous and more or less complex cell aggregates, having a close and uniform anatomic and physiologic connection. They may or may nat be very extensive. A tissue may also be defined as the material structure of an organ.

A mesh-work of connective tissue cells forms a tissue by itself, but not quite complete, as vessels for the conveyance of nourishing blood and the carrying off of deoxidized blood and waste products are necessary, as well as a co-ordinating nervous system. United connective tissue cells, therefore, with their necessary vessels and nerves, form connective tissue. This is the commonest tissue, and it pervades every part of the body, of which it is the great skeleton. Other solid tissues, as a rule, are impossible without it. From this it follows that it must be one of the simplest solid tissues; nearly all the others are more complex. Thus, by filling its meshes with a certain kind of cells and arranging them in the best way to meet the demands of the body, we have a higher tissue. If the meshes are filled with bone corpuscles, or osteo-blasts[2] as they are called, and there is a deposit of calcareous[3] matter, and a certain necessary arrangement, we have bone tissue. Again, suppose the meshes filled with liver cells, and a changed arrangement to meet altered conditions, and we have liver tissue.

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[1] So called because our structures are likened to the products of the loom. Derived from the Latin *texere, textum*—to weave.

[2] From *οστεον*—a bone, and *βλασταvω*—I bud.

[3] From the Latin *calx*—lime.

Higher and Lower Tissues.

From this it follows that tissues, like cells, may be divided into two great classes—the higher and the lower. The higher tissues are those which contain an abundance of special or higher cells, while the lower tissues are those which are composed of only the lower grade of cells, such as the connective tissue and the epithelial and endothelial structures.

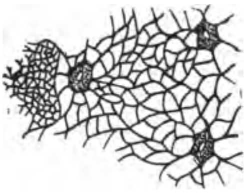
Bichat's Division of Tissues.

Another division, original with Bichat, is into general and special tissues. For instance, the connective tissue, the vessels, and the nerves are general tissues because found everywhere and with always the same object in view; while the osseous, muscular, hepatic and renal tissues are special because not universally present, but only found in particular places for particular work.

Bichat's division is anatomic and regional, whereas the one which it seems best to follow, with the light we now have, is physiologic; at least it is the better plan for a work of this kind. By remembering the lower and the higher tissues, it is always possible to anticipate the course of commencing abnormal changes in a given part of the body by the use of a little reason and the application of principles to be laid down during the progress through these pages. The lower tissues being more general and having greater activity in disease, and therefore giving us most of our general principles, should be the first to meet consideration.

Connective Tissue.

Connective tissue is ever present in all parts of the body. It is modified to meet the special demands of different localities and of various organs; it is the great binding material of the body; it is our true skeleton; its great peculiarity is that it is reticulated; the meshes being large or small, depending upon location and the function of the contained elements. The cell of this tissue has been described. There also exist two kinds of fibrous elements; one called white fibrous tissue, which consists of plain, straight, white, nelastic fibres; the other called yellow elastic tissue, is composed of very light yellow elastic fibres, the ends of which curl upon themselves when severed. The former predominate in the parts where the greatest strength and inelasticity are required, as, for instance, in the ligaments and fibrous membranes, like the peritoneum, pericardium, and dura mater; while the latter is most abundant where great elasticity is needed, notably under the skin in the regions where it is very freely movable, and in such elastic bands as the ligamentum nuchae or the ligamenta subflava.



Connective Tissue, from the spinal cord of man (after Köllicker).

The white and yellow elastic fibres, as well as some others that are not yet fully differentiated from these, serve to insure a stability as well as elasticity to connective tissue which it would not possess if all the binding function depended upon the protoplasmic cellular connections. These fibrils are intimately blended with the connective tissues cells, being frequently embraced by their protoplasmic extensions as the tendrils of a vine do their support.

Adipose Tissue—Fat.

Adipose[4] tissue is one of the simplest modifications of connective tissue. It is composed of cells distended with fat occupying the meshes of the preceding structure. The nuclei of the fat cells can, as a rule, be seen. The average diameter of a fat cell is from 1-600 to 1-300 of an inch. Adipose tissue is found in almost all parts of the body where the simple loose connective tissue exists. It is especially subcutaneous[5], though found to a large extent in the peritoneal reflections of the abdomen, and about the kidneys and heart. Fat often accompanies the blood vessels, as, for instance, in the mesentery and heart. This tissue serves to fill irregularities, being found around joints just outside the synovial membrane;

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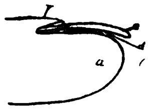
[4] From the Latin *adiposus*—fatty, from *adeps*—fat.

[5] From the Latin *sub*—under, and *cutis*—skin.

sometimes it also fills loose synovial folds that project into a joint, for instance, the ligamentum mucosum and ligamenta alaria of the knee. The spaces above the zygomatic arch[6] and below the malar or cheek bone contain large fat deposits, and these also occur between muscles and tendons to round the superjacent surface. Women have more fat than men. It is normally deposited in large amount during puberty, especially in girls, who then have their angles rounded off by ample deposits of this tissue, and thus acquire a beautiful and attractive figure. Adipose tissue is never found in some parts, such as the lungs, cranial cavity, and subcutaneous connective tissue of the eyelids and penis.

Epithelium.

Epithelial tissue includes all kinds of epithelium, the cutis, nails and hairs. Many epithelial tissues are found in different organs, of which some will be described in their proper places. The cutis,[7] cuticle,[8] or epidermis,[9] the false skin, consists of a deep layer of elongated cells having a granular protoplasm, and a superficial layer composed of more or less dried and flattened cells, of which many are devoid of nuclei. The former layer is called the rete mucosum.[9] Its lowermost cells, for several layers, stand vertical against the subjacent cells of the integumentary papillae. Those of succeeding layers gradually become more elongated, somewhat flattened, and assume a horizontal position. The deep cells contain the pigment granules that color the negro's skin, and which cause the permanent discoloration seen in any skin. The upper



Section of Finger Tip (diagramatic view). *a*, pulp; *b*, fold of cutis; *c*, nail; *d*, intermediate bed of soft cells.

[6] The bridge of bone passing backwards from the cheek-bone to the ear.

[7] From the Latin *cutis*—skin.

[8] From *επ*, *εφ*, *επι*—upon, and *δερμα*—skin.

[9] From the Latin *rete*—a net, and *mucus*—a slimy secretion of mucous membranes.

layers are composed entirely of flattened and more or less dried cells, the most superficial ones being only slightly adherent, thus readily coming away through the friction of clothing and washing. It is this latter, or upper, layer of the false skin that separates from the deeper layer, or rete mucosum, in a blister.

Nails are but epithelial outgrowths from a fold of the cutis, and consist of very compact layers of hard, dry cells. They are connected below with a bed of softer cells from the subjacent cutis. Hair is a like outgrowth from a pouch of the cutis.

Membranes.

Membranes[10] consist simply of a connective tissue framework containing either epithelial or endothelial cells with an adequate supply of vessels and nerves. They, therefore, properly come under the heading of lower tissues. They are essentially of two kinds, serous and mucous, though Bichat, who made a good classification, as he did all things well, makes other groups, as for instance, the fibrous, in which he includes ligaments. But ligaments are also of the lower type. They contain white fibrous tissue, which is very dense, firm and unyielding.

Bichat's Division of Membranes.

It is well to recall Bichat's division of all the mucous membranes of the body into two grand communicating series. The greater is the respiratory-digestive membrane, extending from the ears and Eustachian tubes, and conjunctivae and nasal ducts, to the pharynx and nose respectively, and thence passing the mouth to enter the lungs and the intestinal tract. The other membrane is the genito-urinary, more complex in woman than in man, and in her communicating with the peritoneum by means of the Fallopian tubes.

The ground work or support immediately underlying epithelial cells, and rather closely adherent to them, is often largely composed of protoplasmic extensions from the bases or adjacent surfaces of the cells. The basement membrane is frequently thus formed.

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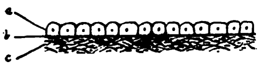
[10] From the Latin *membrana*—a skin covering, and originally of a limb, from *membrum*—a limb.

Epithelial cells are often united by lateral extensions called prickles, which unite with similar outshoots from adjacent cells, thus establishing direct protoplasmic connections between them by means of these so-called inter-cellular bridges.

Mucous Membranes.

Mucous membranes[11] always have a free surface and are moist. They are attached by their other surface to underlying structures by connective tissue called the sub-mucosa.[12] This contains vessels and nerves. The attachment of the membrane may be very firm, as in the cavity of the uterus, or more or less loose, as in the interior of the stomach. Mucous membranes have little elasticity, and that is why they are thrown into deep folds in the stomach during the contraction of this viscus. In the intestines, the membrane is arranged in folds of a semilunar[13] shape around the interior of the small gut, like so many crescentic shaped flaps. These may be either partly or wholly obliterated, depending upon the looseness of the sub-mucosa, but, as a rule, total obliteration is not possible. In the vagina and in the cervix of the uterus, there are also marked and permanent foldings of this membrane. Mucous membranes, because of their inelasticity and lack of tenacity, are delicate and easily torn. They are very vascular[14]; in other words, rich in vessels.



Structure of Mucous Membranes (diagramatic view). *a*, epithelial cells; *b*, basement membrane; *c*, submucosa.

In structure, mucous membranes bear a close resemblance to the skin. This is but natural, as they are continuous at the eye, ear, nose, mouth, anus, prepuce and vulva. It, therefore, has also a superficial and a deep layer. The former is composed of epithelium, and is the corresponding portion of the skin, while the latter is composed of a more complex fibro-

[11] From *mucus*—a slimy secretion, or juice, and *membrana*—skin.

[12] From *sub*—under, and *mucosa*—signifying the mucous surfaces generally.

[13] From *semi*—half, and *Luna*—the moon.

[14] From *vas*—a vessel, and *vasculum*—a little vessel.

vascular structure. Between this and the epithelium is a fine basement membrane[15] composed of flattened epithelioid[16] connective tissue cells. The fibro-vascular layer is composed of connective tissue of varying looseness and density, containing different proportions of white and yellow fibres, and vessels and nerves. The nerves and vessels form plexuses[17] and supply the upper layer. In situations like the hard palate, nose, and interior of the uterus, there is little of this layer and that is dense.[18] Many mucous membranes have small muscular fasiculi in their deepest parts to cause its contraction at suitable moments; such exist, for instance, in the small gut, where they serve to change the direction of the villi; they also aid the circulation through the lymphoid follicles of mucous membranes by their rhythmic contraction and consequent compression of the follicles.

Serous Membranes.

Serous membranes[19] consist of a thin basement membrane of connective tissue, white and yellow fibres, vessels and nerves, having upon its surface one or more layers of flat endothelial cells lying edge to edge. Occasionally there are open spaces communicating with spaces in the underlying connective tissue or basement membrane, and these with the lymphatics. Serous membranes are very thin, in fact, usually transparent, inelastic and remarkably tenacious for a structure so delicate. They line closed cavities like the pericardium, pleurae, peritoneum, arachnoid and joints, the last being called synovial membranes.

Cartilage.

Cartilage or "gristle"[20] is a peculiar tissue in several ways. It is very firm and elastic, has a homogeneous intercellular[21] substance or matrix, and is the precursor of all the bones except such as are formed in membrane, like the bones of the cranial vault. Hyaline[22] cartilage is the typical variety, and is found most perfect in young, unossified bones. Its matrix is perfectly homogeneous and translucent, even transparent, and may be slightly granular. The cells occur singly or in groups, but usually in groups, and have a well marked nucleus. In articular[23] cartilage the cells are smaller, nearer together and more uniformly dispersed than in other varieties. Elastic cartilage, also called yellow because of its color, contains in its matrix bundles of yellow elastic fibres between which are found masses of cartilage cells. This variety is found in the epiglottis, cornicula laryngis and the cartilages of the ear and the Eustachian tubes. White fibro-cartilage differs from the last in having an abundance of white fibrous tissue in its matrix instead of the yellow variety. It is found in the inter-articular fibro-cartilages, as the semilunar of the knee; the marginal fibro-cartilages, as the cotyloid and glenoid; connecting fibro-cartilage, such as unite the pubic symphisis and vertebrae; and the lining and sesamoid fibro-cartilages found in the grooves for some tendons.

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[15] Also called primary or limiting membrane, and *membrana propria.*

[16] From *epithelium* and ειδος—like.

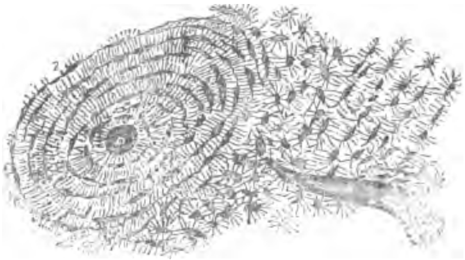
[17] From πλεκω—I interlace; I entwine.

[18] It is claimed by many gynecologists that the membrane of the body of the uterus has no underlying connective tissue, holding that it rests directly upon the muscular wall.

[19] From *serum*—a thin or watery fluid, which they secrete or exude.

[20] From *cartilago*—gristle.

[21] From *inter*—between, and *cellular*—pertaining to cells.



Section of Bone (magnified), showing Haversian canal in oblique, longitudinal and transverse section, surrounded by concentric layers of lacunae and canaliculi (Virchow).

Bone.

Bone consists of connective tissue having in its meshes bone corpuscles. These corpuscles evolve calcareous material and pass it into the surrounding tissue, thus making them hard, firm and unyielding. In this way each corpuscle prepares for itself a hard resting place, or veritable cavern, called lacuna.[24] Communications are established between these cells of bone, or osteo-blasts, by small canals called canaliculi.[25] Nourishment is brought to the osteo-blasts through hard bony channels, called Haversian[26] canals. These are lined with endothelium resting upon a basement membrane. Blood is conveyed to the bone cells from these canals through the canaliculi, in which are also lodged processes (protoplasmic extensions) of the bone cells communicating with like offshoots from neighboring cells. In this way there is formed a laminated[27] system of osteo-blasts around each Haversian canal, and such a cylinder is known as a Haversian system. These are characteristic of bone. Tissues which become stone or bone hard, and have not this arrangement, are said to be calcified, only those being ossified which have genuine Haversian systems.

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[22] *Hyalinus*, from ὑαλος—glass.

[23] From *artus*—a joint.

The space in the lacunae, canaliculi, and Haversian canals between the hard walls and their soft contents is filled with lymph, which acts physically as a protection and chemically as it does elsewhere.

Blood Vessels.

Blood vessels are of several kinds. The capillaries[28] form one of the simplest tissues, consisting only of flattened cells lying edge to edge and forming a hollow cylinder. They imbibe their nutriment from the passing blood current. Large vessels, as, for instance, the radial, brachial, tibial or femoral, have a triple coat. The three coats are known from within outwards as the intima, media, and adventitia. The intima[29] is simply a lining of endothelial cells with a subjacent fine basement membrane. The media[30] is composed of circular and longitudinal muscles. The circular muscles are next to the intima, and the longitudinal are in contact with the adventitia.

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[24] A lake.

[25] Diminutive of *canalis*—a canal.

[26] Named after Havers, who first described them.

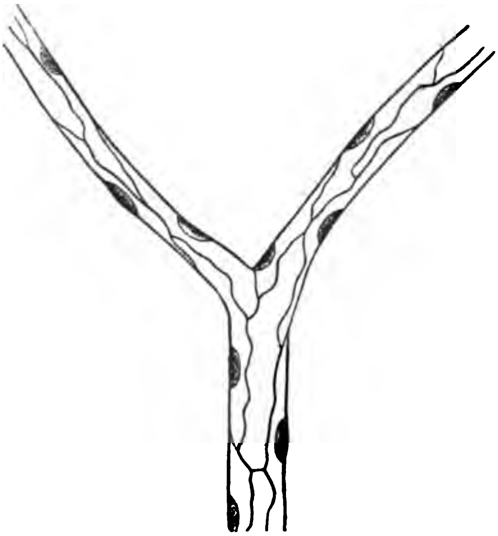
[27] From *lamella*—a plate.

[28] From *capillus*—a hair.

[29] From *intimus*—the inmost.

[30] From *medius*—the middle.

A rule worth bearing in mind is that nearly all hollow viscera, as well as ducts and vessels, have circular or transverse and longitudinal muscle fibres, and that the circular or transverse are internal to the longitudinal.



A Capillary, an enormously enlarged view, showing how it is formed of a single layer of cells fitting edge to edge (Köllicker).

The adventitia[31] is a more or less dense connective tissue sheath, having no abrupt termination, but which shades off rather suddenly into the surrounding tissue. The largest vessels, like the aorta, have no muscular tissue, but instead have a media composed of yellow elastic tissue. The veins have about the same structure as the arteries, but are thinner, have a greater calibre, and yet are more tenacious. These tunics are subdivided, a fine elastic layer existing upon the inner and outer side of the media, and the adventitia being divisible into two portions.

Lymphatics.

Lymphatics[32] are very thin—in fact, in some instances transparent; they have three coats. The inner has an endothelial lining with longitudinal elastic fibres as a basement membrane. The middle coat is made up of circular muscle fibres and reticulated elastic fibres running in the same direction. The outer coat is composed of connective tissue, longitudinal elastic fibres and an intermixture of muscle fibre running in all directions, but least in a longitudinal direction. The lymphatic radicals, like the capillaries, consist only of a simple layer of endothelial cells with very irregular and wavy borders. These radicals, or rootlets, open into the spaces of connective tissue called lymph spaces, and serve to carry off waste products and poisons. The lymph spaces of the connective tissue are lined with the same kind of cells found making up the lymph radicals.

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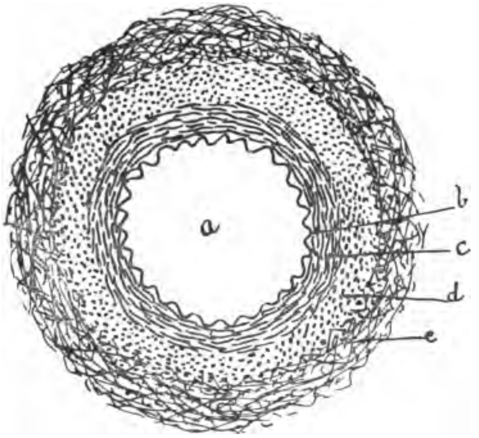
[31] From *ad*—to, and *venire*—to come; something added, but not essential.

[32] From *lympha*—lymph; a vessel conveying lymph.



Section Through An Artery (diagramatic). *a*, lumen of vessel; *b*, intima; *c*, inner layer of circular muscles; *d*, outer or longitudinal muscles; *e*, the connective tissue sheath of the vessel, called the adventitia or outer coat.

Lymphatic Glands.

Lymphatic glands,[33] also called conglobate[34] glands and lymphatic ganglions,[35] are found interrupting the course of the lymphatics of the trunk, head and limbs. This tissue consists of a connective tissue framework forming a firm capsule and sending partitions toward the centre, thus dividing the gland into so many compartments or stalls. These are filled with prolongations of connective tissue from one partition to another, dividing the compartments into numerous large connective tissue spaces. About the central half of the compartment meshes are filled with lymphoid cells or leucocytes. This is called lymphoid tissue and is quite soft. The remaining meshes between the lymphoid collection and the partitions are filled with passing lymph delivered to the gland by the afferent[36] lymphatics and taken away by the efferent[37] vessels. It is also interesting to note that the efferent vessels are fewer in number and larger in size than the afferent vessels.

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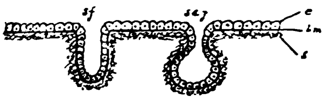
[33] From *glans*—an acorn; a kernel.

[34] From *con*—together, and *globus*—a ball.

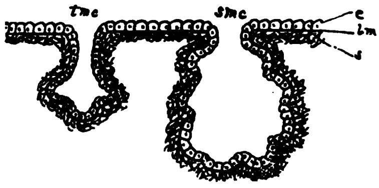
[5] From γαγγλιον—a knot.

Secreting Glands.

Secreting glands are identical with the mucous membranes as regards plan of structure. It will be remembered that the mucous membranes are composed of an upper epithelial layer, a subjacent basement membrane, and an underlying submucosa containing vessels and nerves. Suppose such a membrane be indented and we have a follicle[38] as, for instance,



Simplest Form of Glandular Structure (in diagram), *i. e.*, by invagination of mucous membranes; *e*, epithelium; *bm*, basement membrane; *s*, submucosa; *sf*, simple tubular follicle; *saf*, simple sacculated follicle.



Less Simple Form of Glandular Structure (in diagram). *e*, epithelium; *bm*, basement membrane; *s*, submucosa; *tmc*, tubular multilocular crypt; *smc*, saccular multilocular crypt.

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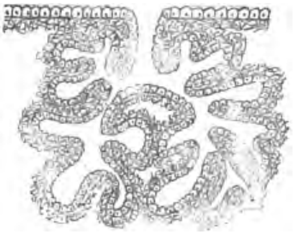
[36] From *ad*—to, and *fero*—I carry.

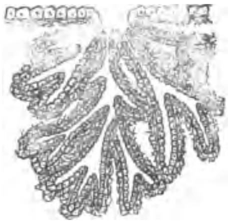
[37] From *e*—from, and *fero*—I carry.

[38] Diminutive of *follis*—a bag.

those of Lieberkühn in the small gut. These are the simplest forms of glands. Suppose a large indention with branches, and we have a compound gland. Again, suppose a bulging out of the membrane and the sub-division of this chamber into compartments along its wall, and we have a multilocular crypt[39] or simple sacculated gland. In case there are branching tubes with saccular expansions, it is called a compound saccular, or racemose gland. If there are simple branching tubes, it is called a compound tubular gland. In all these instances, no matter how complex the division of the branches from the original opening in the membrane or surface, all the tubes and sacs consist from within outwards of, first, epithelium; second, a basement membrane; and third, the submucosa.



Compound Saccular or Racemose Gland (in diagram).



Compound Tubular Gland (in diagram).

Vascular or Ductless Glands.

The so-called vascular or ductless glands[40] are the spleen, thyroid body, thymus gland, supra-renal capsules, pituitary body, solitary and agminated follicles of the gut, follicular glands at the base of the tongue, and the lymphatic glands. They are all made upon one general plan, and that is the presence of varying amounts of lymphoid corpuscles, called lymphoid tissue when collected in masses in the connective tissue framework of the organ, and a large number of blood and lymph vessels. In some, as for instance the spleen, the lymphoid cells are collected in groups and form the Malpighian bodies; in others, they are rather evenly distributed throughout the entire structure of the gland, so-called, as in the thymus; in some others again, they are found in patches with lymph channels between, as in the lymphatic glands.

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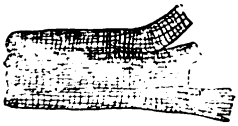
[39] From *multus*—many, and *loculus*--little place, and κρύπτειν--to hide.

[40] So called because they are quite rich in vessels, and have no excretory duct.

Muscle.

Muscle is of two kinds; the predominating variety consisting of transversely striated fibres composed of seemingly superimposed disks. This is striated muscle, and is also known as voluntary muscle because nearly all such is under the control of the will. The other variety is non-striated, and consists of long filiform[41] and somewhat wavy fibres. These have, in about the centre, an elongated oval nucleus. This kind of muscle is designated involuntary because it is not under the control of the will. It is found in the internal organs and walls of the hollow viscera and ducts. In both varieties the cells are held together by connective tissue as a support to the essential elements, the muscle cells, and their afferent and efferent vessels and nerves. The muscle fibres of the heart, though involuntary, are striated, but differ from other striated muscle fibres in being branched.



Voluntary Muscle Bundles, showing transverse striae.

Involuntary Muscle Cells.

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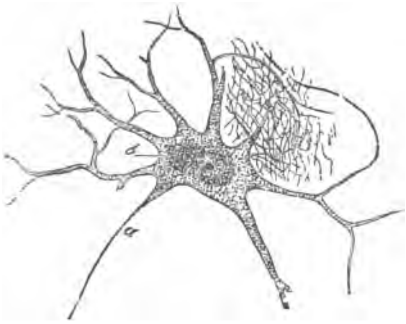
[41] From *filum*—thread, and *forma*—form.

The most recent investigations show that the striations of voluntary muscle are due to the arrangement of its structure into rods of regularly varying thicknesses alternating with narrow intermediate strips, and so arranged that the thicker parts are always side by side. The intervening semi-fluid substance is called the sarcoplasm,[42] while the rods are the real sarcos or muscle elements. The whole is bound in by the thin ensheathing membrane called the sarcolemma.[43] The arrangement of parallel rods with all the thicker segments upon the same level and the much thinner ones intervening between them, cause the appearance of alternating light and dark transverse striations.

Nerve Tissue.

Nerve tissue is also divided into two varieties, called grey and white. The grey matter is composed of nerve cells filling the meshwork of the connective tissue. The cells, having a very granular protoplasm, cause the grey color. The white matter consists of nerve fibres surrounded and held in place by connective tissue. Nerve fibres consist of a dark central, essential part called the axis cylinder, a continuation of the axis cylinder process of nerve cells. This is covered



A Ramified Nerve Cell (Gerlach) from the anterior horns of the spinal cord of man. *a*, axis cylinder process ; *b*, clump of pigment granules. The small fibrils above the cell are found ramifying throughout the cellular nervous tissue, and are supposed to be fine cellular connections. The nucleus and nucleolus are also plainly shown.

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[42] From *σάρξ*—flesh ; *πλάσσειν*—to mould.

[43] From *σάρξ*—flesh ; *λέμμα*—husk.

by a white insulating or non-conducting substance called myeline,[44] having an oily appearance under the microscope, especially under certain conditions when it separates into drops. The whole is surrounded by a delicate sheath of connective tissue. Some fibres have no myeline, or medulla,[45] as it is also called, and hence have been named non-medullated fibres, and because they were first described by Remak they are denominated "fibres of Remak." The presence of myeline gives the white matter and most nerves a glistening appearance, while in those fibres where it is absent the nerves are grey, as, for instance, the sympathetic, the olfactory, or many in the grey matter of the brain, spinal cord, and sympathetic ganglia.

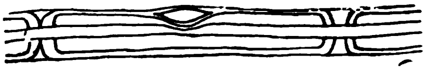

Diagram of Ordinary Nerve Fiber. **Showing axis cylinder in centre surrounded by myeline, which is contracted at some places called nodes (constrictions of Ranvier), and an enveloping connective tissue sheath containing occasional cells, one of which is shown compressing the myeline.**

The Neurone Theory.

The so-called neurone[46] theory so much written about within the past four years is really an amplification of an old idea, but without reference to which this little work might seem antiquated. It is simply this, that the name neurone is given to the nerve cell and its ramifications, inclusive of its axis cylinder process, together with its termination upon a muscle or in some part of the sensorium, say the skin or mucous membrane. This concept has also been put forth by Köllicker under the name neurodendron,[47] and by Rauber as neura,[48] while Waldeyer originated the term neurone. The long extension of the cell, extending from the cell body to muscle to be acted upon or the part from which sensory impressions are conveyed, and long known as the axis cylinder process, is called the neuraxis or neuraxone under the new nomenclature, and means substantially the same thing. It also has other designations, as, for instance, axone, neurite, and Deiter's process, all of which help confuse. The name dendrites has been given to cell branches or extensions that ramify for a short distance, and usually begin more evidently as parts of the cell body, having a broad origin.[48] The neuraxis also differs from the dendrites by being even in outline and of uniform diameter, while the latter are nodular. The terminal endings of all nerve cell processes are called telodendria.[49] Occasionally, a cell gives off more than one neuraxis (axis cylinder process). Many neuraxes branch, and those which do are divided into long and short branches.

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[44] From *μυελος*—marrow.

[45] From *medius*—in the middle.

[46] From *νεῦρον*—nerve.

[47] From *νεῦρον*—nerve, and *δένδρον*—a tree.

[48] From *δένδρον*—a tree.

[49] From *τέλος*—end, and *δένδρον*—a tree.

CHAPTER III.

ORGANS—APPARATUSES—SYSTEMS.

(Tissue Compounds.)

In the preceding chapters we have considered cells, and also their connections and relations called tissues. Another step takes us to the study of the connections and relations of tissues, and these are called organs, things that work—living instruments. They form chains or series, some of which are called apparatuses and others systems, and of this more will soon be said.

Organs.

An organ[1] is merely a complex aggregation of cells for the purpose of performing a special function. Thus a muscle is a collection of muscle cells, and its special function is expansion and contraction. The liver is a mass of cells with supportive connective tissue, and vessels, nerves, and ducts, and its special functions are the higher digestive, the glycogenic, and the biliary. So it is with all the organs of the body, not excluding bone, or skin, or mucous membranes. Whatever part of the body performs definite functions separate and distinct from other parts of the body is an organ. From this it follows that every bone and muscle is a separate organ. It is very important, if we would form a proper conception of medicine from the beginning, and thus pursue our studies to the greatest possible advantage, that we bear in mind the fact that a bone or muscle is as much an organ by itself as is the stomach, or the kidney, or the liver.

Far too much stress has been laid upon the distinction made between organs. The average student—nay even the average practitioner—is so imbued with the notion that the number of the organs in the body is limited, that he cannot see any reason in calling anything an organ besides those of the mind, voice, circulation, respiration, digestion, urination, generation, and a few others. To speak of a bone as an organ seems preposterous to many. They do not know that even an individual cell is an organ per se, while, on the other hand, the total animal body is one great organ, the only difference being that the former is simple and the latter highly complex. To the one who will recollect this simple generalization, that the individual cells as well as the whole body are organs, many of the more comprehensive conceptions that are to follow will retain their natural naked simplicity. The complexity of the human body is real when only the numerous parts and functions are considered, but when viewed with regard to its objects and their practical attainment, the connected whole at once is evident and the problem simplified.

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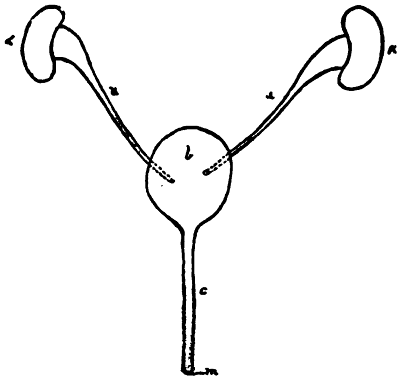
[1] From εργον—work, or an instrument.

Apparatuses.[2]

A single organ is not able to perform all the work necessary to its maintenance. The higher we go in the scale of development, the more forcible is this truth. In many instances a single organ is unable to perform completely a special function, and in such instances there exist a connected series of organs, sometimes widely different, but all tending to the same end, and such a connected series of har-



The Urinary Apparatus (in diagram). *k*, *k*, kidneys; *u*, *u*, ureters; *b*, bladder; *c*, urethra; *m*, meatus.

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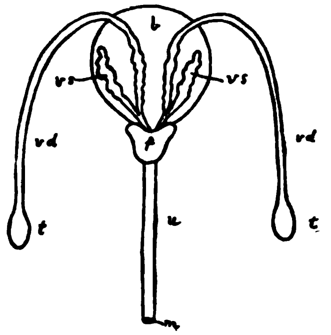
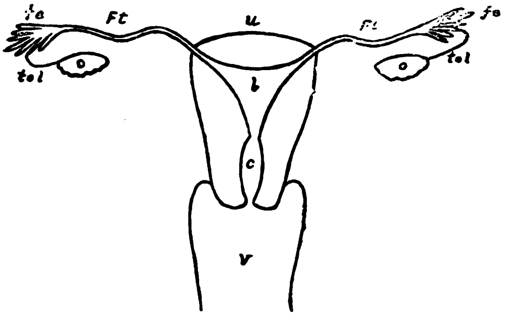
[2] From the prefix *prae*—from, and *parare*—prepare.

moniously working organs is called an apparatus. For instance, we have the respiratory, digestive, genital, and urinary apparatuses. Thus there is included in the digestive apparatus the whole intestinal tract, varying greatly in different parts from the mouth to the anus, and forming parts of it we find the parotid, submaxillary, sublingual and buccal glands (known collectively as the salivary glands), the pancreas, and the liver. Here are a number of organs widely different and yet tending to the same end, i. e., the changing of ingested food so that it may be absorbed into the blood and conveyed to the tissues as nourishment. We have in the respiratory apparatus the



The Genital Apparatus of the Male (in diagram). *t*, *t*, testes; *vd*, *vd*, vassa de'erentia; *vs*, *vs*. vesiculae seminales; *b*, bladder; *p*, prostate gland; *u*, urethra; *m*, meatus.



Genital Apparatus of the Female (in diagram). *o*, *o*, ovaries; *tol*, *tol*. tubo-ovarian ligament; *fe*, *fe*, fimbriated extremities; *ft*, *ft*, fallopian tubes; *u*, uterus; *b*, cavity of the body; *c*, cavity of the cervix; *v*, vagina.

nares, pharynx, larynx, trachea, bronchi, and lungs. The urinary consists of the kidney, the ureters, bladder, and urethra. The genital of the testicles, vasa deferentia, vesiculae seminales, prostate, and penis and urethra in the male, and the ovaries, Fallopian tubes, uterus, and vagina in the female. An apparatus may therefore be said to be a chain or series of unlike organs, more or less connected, for the purpose of performing one or more certain functions. Thus we see that an apparatus is composed of organs, that these are formed of tissues, and that they in their turn are made up of cells, or, in other words, anatomic elements.

Systems.[3]

When, however, there are two or a number of organs similarly constituted, so that the examination of a part of one does not reveal from which region of the body it comes, they form a system. Such are the osseous, muscular and nervous. All muscles are alike, and microscopic sections of one look like those of any of the others. The same is true of bone and of nerve tissue in the main. The functions of the different organs of a system vary with the location of its parts. For instance, a certain bone, say the humerus, helps to form the shoulder and elbow joints, gives attachment to certain muscles, supports the forearm at an unchangeable distance from the shoulder, and aids in giving stability and power to the upper limb. The radius and ulna aid in the formation of a different part of the elbow joint than does the humerus; they afford attachment to other muscles, or different parts of the same muscles; they keep the hand an unvarying distance from the elbow, and give general support to the structures of the forearm. The functions of the thigh bone differ from either of the preceding, and the same may be said of any bone compared with any of the others, so that the system of bones subserves very many useful purposes. The muscle of the front upper arm, the bicep, is identical in structure with the muscles of the chest, belly, thigh, and calf, and yet its function is different: it bends the elbow and approximates the hand to the face or shoulder, it also supinates the hand, or turns it palm up. The muscles of the calf raise the heel and with it the body if the person is standing. These instances may be multiplied indefinitely, especially as regards the nervous system, in which different nerves carry impressions from different regions, and bring to our conceptions sensations differing widely in kind and intensity, and yet the nerve fibres are all alike in structure. The sensations they convey depend upon locality and cause.

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[3] From *συν*—together, and *ιστημι*—I place.

The difference, therefore, between an apparatus and a system is that in the former there is an association of different kinds of organs performing varous functions tending to the same end, while in the latter there are a number of organs exactly alike, associated or not, and always producing similar effects towards different ends. In other words, unlike organs connected to perform varying functions tending to a common end constitute an apparatus, and like organs unconnected and performing similar functions tending to various ends form a system. The terms of one proposition are somewhat the reverse of the other as regards the variety of organs and singleness of end on the one hand and sameness of organs and multiplicity of ends on the other.

Now which is right, vascular or circulatory apparatus or vascular or circulatory system? Let us see. The whole vascular machinery is divisible into two parts, the lymphatic and the sanguineous. The lymphatic has lymph-spaces, lymph-vessels, and lymphatic glands, and lymphatic ducts. Its vessels are closely studded with valves. Here are several different organs tending to one end, i. e., the circulation, or transmission, and the transformation of lymph. It is, therefore, an apparatus. On the other hand, we have the heart, arteries, veins, and capillaries. Here also are four distinct organs tending toward the same end, so that of this arrangement we must also say apparatus. All the arteries are in the main alike, however, and each tends to some different end, i. e., the nourishment of a special tissue territory or cell brood. So we can say arterial system, venous system, capillary system, but we must say circulatory apparatus. Again, we have the lymphatic glandular system and the lymphatic vascular system, while collectively they are denominated lymphatic apparatus.

CHAPTER IV.

OUR BODY.

A Complex Cell Aggregate.

We have learned that cells are anatomic units; that cells, when normally connected, form tissues; that tissues in their entirety form organs, or things that work; that these organs are usually arranged in series to perform certain kinds of work, and are divisible into two classes, called apparatuses and systems. We shall now find that all of these cells, tissues, and organs, together with the arrangement into apparatuses and systems, form one great connected whole, a vast complex organ, or working and thinking machine, called the body. This great and wonderful body of ours is a large organ, for it exists to do work; it is an instrument. Looking upon the living, thinking engine, and considering its millions of units and their innumerable connections, makes it seem bewilderingly and incomprehensibly complex. The number of facts stagger the understanding. The mind is tired and the student discouraged. It seems that so many facts can never be memorized, but they certainly can, and the incredulous and hopeless query of the learner as to how this is to be done, is met with the statement that the mastery of simple principles and generalizations will reduce the number of facts within comprehensible limits. What these are will appear. Some have already been stated, as, for instance, the generalization that all glands are multiple pockets of the mucous membrane upon which they open.

The body is a collection of organs, systems, and apparatuses tending to the same ends that are originally found in the ameba and the protameba, i. e., ingestion, egestion, work, growth, and reproduction. The only difference is that man is a highly complex organism. All high organisms are very complex, and this complexity serves to bring them in more conscious relation with other like and unlike organisms. Man is the highest and, therefore, the most complex of all the organisms, and the most nearly perfect. The most complex, the highest grade development we have is in our nervous system. It is the latest development, and in case of retrograde or downward changes, either in eventual dissolution or in the descending scale of organisms, it is, in the main, the first to be modified or lost. The interdependence of the various parts is complete, so that cessation of function in some necessarily entails a stoppage in others,, and in several instances, as in the nerve centre of the medulla,[1] a comparatively minute disturbance wrecks the whole organism.

The body as a whole must be viewed as any of its simplest elements, in short, as we would an ameba. It ingests, works, grows, egests, and reproduces itself. The cells and tissues already described make up the organs, apparatuses, and systems of the body. Our ingestion, digestion, and egestion is accomplished mainly by the alimentary tract and its appendages, i. e., the digestive apparatus. The food, divisible into carbo-hydrates,[2] fats, and albuminoids,[3] enters the mouth and passes down the gullet into the stomach. Carbo-hydrates and fats are acted upon to a certain degree in the mouth by the saliva.[4] This action ceases in the stomach, where the albuminoids undergo a change. In the small gut all kinds of food are digested, but the fats and carbo-hydrates are not actively changed. Food is absorbed through the stomach and intestinal mucous membrane. The fat is carried away by the lymphatics[5] (lacteals) to the thoracic duct and thence to the left sub-clavian vein to the heart. It can be traced in the blood to the lungs, but not through them. The carbo-hydrates and albuminoids are carried to the liver by the portal vein, where they undergo final digestion before being admitted to the main circulation for general distribution. Egestion, or elimination, takes place through the larger bowel, kidneys and lungs, some also taking place through the skin.

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[1] The upper end of the spinal cord, called *medulla oblongata*, meaning "oblong marrow."

[2] Carbo-hydrates are substances composed of carbon, hydrogen and oxygen, with the last two in proportion to form water.

[3] Albuminoids are substances that contain nitrogen, and have the general chemic constituents of albumin.

[4] The saliva is the spittle; its active principle is ptyalin.

[5] The lymphatics of the mesentery are called lacteals from *lac*—milk, because the fat they carry during digestion has a milky appearance.

Body Growth.

The growth of the body is interesting, as is the question why we stop growing when we do. This is readily explained by the changing relative size between the alimentary canal and body from birth to adult age. At first the gut is much too large to supply only the waste of the body, and so all excess goes to additional growth and development. The growth of the body is rapid and overtakes that of the intestines in from twenty to twenty-five years. Then body growth is at a stand-still. For years afterwards the intestinal capacity is simply enough to supply waste. Then it deteriorates, as does the body generally; there is a wearing out. In proportion as the body degenerates, more work is required of the digestive tract, and this, also partaking of the general degeneration, is less able than before to meet the increasing strain. In this way the end soon approaches. This is the degenerative phase of life or period of decay. The weakest part of any particular organism or individual usually breaks down first. If the life is a normal one, the individual will eventually die of old age, or senility.[6] The time for this would depend upon the inherent quality of each organism as well as the strains to which it had been subjected during its existence.

Body Work.

The work of the body is of two kinds, the physic and the psychic. The former is due to active muscular expansion and contraction, causing the movement of hard structures, like the bones, and of soft parts of the body, as the skin of the face. The other is evidenced by mental action, especially that which is idealistic or abstract, as it is voluntary, disinterested and subserves no directly useful purpose, such as supplying food to the organism.

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[6] From *senex*—old.

Reproduction.

Reproduction requires two elements, the ovum and fecundating material. The ownership of either one of these constitutes sex. The ovum belongs to the female, the fecundating element to the male. Contact of these two elements while living, and under circumstances favorable to continued existence while together, forms the only condition of successful impregnation and reproduction.

Nourishment.

We breathe for the purposes of furnishing our cells with oxygen and relieving them of carbonic oxide (carbon dioxide). The blood current is the medium by which this is accomplished, as is nourishment. Just as we have the food prepared in the digestive apparatus before it is carried to the cell brood, so also does aeration and oxidation take place in the respiratory apparatus. The blood vessels, except capillaries, do not absorb their nutriment directly from the passing blood, but receive it from the minute ramifications of vessels that branch off like little twigs from the vessel itself, and run upon its surface for a very short distance and then dip down between its coats to furnish it with its own contents. Essentially the same system prevails in the digestive tract. The digested food is in the stomach and gut, but is not absorbed directly to nourish these structures. It first passes into vessels, and through the heart, lungs and heart again before the organs that prepared it get their supply. This process may be likened to the manufacture of food in large factories, which, though prepared by the workmen in the building, is not consumed by them except after being purchased in the regular market.

The complexity of our bodies is more seeming than real. More careful study than is commonly given to this subject will reveal that the closeness of relation and intimate connection of our various parts, instead of adding to the complexity, actually simplify the anatomic structure and physiologic processes. It has often been held that the compactness of our mechanism was due to the necessity for economizing space, else we might grow to twice our present height. There is no warrant for this supposition for several reasons. The tallest men and women are built proportionately just as compactly as the smallest of their kind. The massive elephant is as compact in his proportions as is the little mouse. Again, there is plenty of space in Nature to accommodate beings much larger than those which now exist. There is no necessity for economy in space to such an extent that Nature could not afford to accommodate human beings having an average stature of 16 or 20 feet as well as 5 feet 6 inches. There is, moreover, a difference of fully thirty per cent. in adult human stature at the present day. Some are over 6 feet, while others are hardly over 4 feet in height. Adductions of this kind could be made very numerous, but a few suffice.

Respiration and Circulation.

Lack of space forbids more than a mere mention of the relations of some parts of our organism. Respiration and circulation are inseparably blended. They harmonize with each other and with other parts of the body, as, for instance, the abdominal movements. It is a mistake to account for the coincident abdominal contraction and thoracic expansion, and vice versa, upon purely mechanic principles. The deciding or guiding factor is the central nervous system. It is wrong to suppose that we naturally only expand the chest through an active nerve centre, and that this expansion causes in a purely mechanic way either the bulging or retraction of the belly. The nerve centres cause both actions at one and the same time, either, if necessary, going on rhythmically without the other. This has been proved by Triplett,[7] who severed the chest from the abdomen, but without injuring the spinal column, and then plainly observed the rhythmic and complementary alternate contraction and relaxation of the chest and abdomen. He, at the same time, proved an alternating high and low pressure in the belly during other movements. The abdominal movements cause alternate rhythmic compression and relaxation of its contents. This periodic compression forces towards the heart the flow of venous blood through the large veins of the abdomen, for it cannot recede because of the valves in the veins. The same alternate compression aids digestion by moving the food and hastening absorption, for we all know that absorption is hastened by pressure. Liver circulation and digestion is particularly improved by the complementary thoracic and abdominal movements. The alternate compressions and relaxations of the liver greatly aid the portal circulation, and hence increase the activity of the liver. A torpid liver is a sluggish one, and many such can be best overcome by deep and rapid breathing, such, for instance, as follows brisk running.

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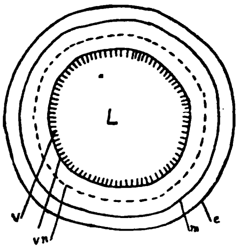
[7] In his incomparable book on "Life; Its Laws and Mechanics."

Intestinal Absorption.

The pressure of gas in the small gut has a useful purpose. We know that albuminoids do not osmose[8] readily through animal membranes, and the mucous membrane being an animal membrane, much surprise was expressed at one time by physiologists as to how the food passed into the intestinal walls and blood vessels. It is, and was then, well established that albuminoids pass through animal membranes under pressure. It is just at this juncture that the presence of gas in the intestines is beneficial. The gut has three coats, an internal or mucous, an external or serous, and a middle or muscular. Between the mucous and the muscular coats is found a ramifying network of blood and lymph vessels, and nerves. The free surface of the intestinal mucous membrane is studded with numerous villi or teat-like processes. These are to increase the absorbing area of the gut. Suppose now some liquefied albuminous food in the small gut. It is ready for absorption. It is mingled with intestinal gas. The muscular coat contracts. This compresses the gas and increases the intra-intestinal pressure without bruising the delicate mucous



Section of the Small Gut (in diagram). *l*, lumen of the gut; *v*, villi; *m*, mucous membrane; *vn*, vessels and nerves; *m*, muscular coat; *e*, endothelial (peritoneal) coat.

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[8] From ωσμος—impulse.

membrane. The air acts as a soft elastic cushion. If there is too much gas, the gut becomes unduly distended, and this causes uneasiness. This uneasiness leads to a spasm of the muscular coat in some narrow area, and the result is a marked band-like constriction of the tube at one place, giving rise to a sharp, grasping, griping pain, continuing during the constriction. This is colic.

The Production and Regulation of Heat.

The production of heat is dependent upon chemic and physic causes, all of which are largely furnished by the processes of respiration, circulation and digestion; the remainder may be said to come from voluntary work of all kinds.

It is the business of the nervous system to complete this mechanism by being its regulating automatism. Respiration, circulation and digestion cause and keep up the bodily temperature. The work of these apparatuses is remitting in character, and hence there is not uniform production of heat. Still the body temperature is maintained at a practically uniform standard. This is variously given at from 98½ degrees Fahrenheit to 100 degrees Fahrenheit. The difference depends upon how and at what part of the body the record is taken, being highest in the rectum and lowest in the axilla. That heat production can be lessened, even at will, is at once evident when we recollect that respiration and circulation are under our control as far as being active or passive is concerned; and digestion is altogether so, for it requires voluntary action for us to ingest food. There must be a method for disposing of all excessive heat production. This is also voluntary as well as involuntary. Voluntary, as evidenced in the various methods of keeping cool when we feel the involuntary method to be inadequate. The involuntary method consists in the direct radiation of heat from the body as well as in its abstraction by the evaporation of the perspiration. When the natural means for the disposal of surplus animal heat is overtaxed, the body temperature rises and the central nervous system feels the change. This causes a depression of the circulatory, respiratory and digestive processes, and consequently a lessening of heat production. This is the normal way. In speaking of abnormal conditions further on, more will be said upon this subject.

Reflex Action.

The role of the nervous system in the mechanism of the body is most important, as it is the great connecting bond between all its parts. Its actions are characteristic in being reflected. In physics we say of reflected light that the angle of reflection equals the angle of incidence, and this same principle may be applied in a figurative sense to the operations of the great nervous system. Essentially, this consists of a ruling or controlling centre with two sets of nerves, one afferent, conveying impressions from the periphery to the centre, and another efferent, carrying impulses outwards from the centre. Suppose one in bare feet unexpectedly steps upon a red-hot coal. Almost instantly the impression is carried to the nerve centres in the spinal cord; these are stimulated to action and send a sudden impulse along the efferent nerve to the muscles of the leg, which promptly contract and thus retract the injured part. In this way an impression is carried to the centre and is thence reflected to the periphery. The intensity of the reflected nervous force bears a close relation to the amount of incident irritation or excitation coming to the centre from the periphery. So that even here we have an analogy with the law of physics to which allusion has been made.

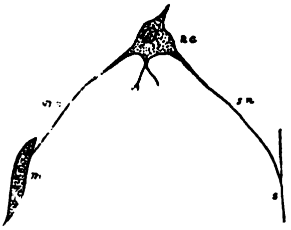

Diagram Illustrating Reflex Action. ***s***, skin (the sensorium); ***sn***, sensory nerve; ***nc***, nerve cell; ***mn***, motor nerve; ***m***, muscle.

Suppose again that the eye sees a base ball coming directly towards it at rapid speed; the impression is quickly carried back, its significance instantly weighed, and an impulse sent along to the proper bodily muscles in time to ensure a sudden timely turn, jump, or stoop, as may appear best. This is reflex action, and it is characteristic of the nervous system.

From what has briefly been outlined, it may readily be seen that we are compactly made of organs and sets of organs, or apparatuses and systems; that these all work in harmony; that their business is to ingest, digest and egest, i. e., maintain life; the change of material passing through the body, and of its own relations, i. e., work; the propagation of itself indefinitely in giving origin to similar organisms, i. e., reproduction. Thus is shown that we resemble the ameba in principle and differ from it only in degree; in fact, each one of us is a huge mass of myriads of ameba; in other words, we are complex, systematic organizations of cells for the purpose of living a comparatively long life, working nearest the highest degree of perfection, and continuing ourselves indefinitely by reproduction.

CHAPTER V.

CELL NUTRITION.

The nourishment of cells is an important study, inasmuch as a great deal of our understanding of the modes of action of medicines depends upon our knowledge as to how drugs are conveyed to cells, for they cannot be considered as incorporated in the body until absorbed by the cells themselves.

Essentially, the cells of our bodies are nourished in the same way as the ameba, with the exception that their food is generally in a liquid medium and brought directly to them, instead of their having to go in search for it themselves. Nerve, bone, muscle and fibrous tissue exert themselves to apprehend food, while the digestive apparatus limits itself to making it over into the circulation, and the latter takes it to the cell brood. These different apparatuses and systems form a connected, harmonious whole. The nervous system is a great co-ordinating power, regulating action and interaction, stimulating work to a required extent on the one hand, while it inhibits or prohibits work when labor has been excessive.

The cells imbibe their nutriment from the blood flowing through adjacent vessels. The cell of the capillary wall imbibes its nourishment from the contained blood. The cells of the arterial coats derive their food from the vasa vasorum, or vessels of the vessels, which are minute branches given off from the arteries that turn back and enter the arterial coats to supply the requisite pabulum. The cells of cartilage, especially hyaline cartilage, with apparently no vessels near, absorb theirs through a homogeneous matrix from the nearest vessels. All cells, as we shall see later, have the ability to absorb food through some distance. This, however, is limited and differs with various cells. The natural consequence is that if the blood supply is cut off, as, for instance, in the occlusion of a vessel, nearly all the cells in that area will starve to death unless the blood can get to them through collateral[1] channels. If there are none such, all the area except those in its border soon die, and the latter subsist through their power of absorbing food from a distance, and the amount of border cells that will in this way be saved from starvation will depend upon the distance from which they are able to absorb enough food to live till new vessels have grown into the stricken district. This ability differs with the kind of cells and with the previous vigor of any given variety of cells.

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[1] From *co*—a prefix signifying with and together, and *latus*—side.

Cell nutrition is directly dependent upon circulation, blood or lymph. That there are some exceptions, especially in some so-called pathologic conditions, is a fact. As a rule, though, there is no pabulum near a cell except that which comes through the blood or lymph vessels. Food may be introduced on the mucous and external integumentary surface or injected hypodermically; but these processes are artificial, and have no place in the consideration of normal physiology except as curiosities.

Even in those instances in the body in which cells imbibe their nourishment from pabulum not directly absorbed from the blood or lymph, they are indirectly dependent upon the circulation, because the pabulum they otherwise thrive upon is directly resultant from the circulatory blood, so that, without exception, the cells are dependent either directly or indirectly upon the continuance of the blood current. The current may cease for a time, in fact for some hours, without permanent damage, but if persistent, death of the tissues in the deprived district is inevitable. This area may be microscopic in size, or may involve a whole organ or extremity, or may implicate the entire body. In the latter event it is called somatic[2] death, and is well illustrated in sudden deaths due to heart wounds, where the main disturbing factor is inhibition of circulation.

Cellular and Somatic Death.

When a cell or number of cells die, it is a cellular death. When the body as a whole has ceased to act, it is somatic death. Somatic death is a fact when what Watson has called the "tripod of life," that is the brain, heart and lungs, no longer functionates. At this time, while the death of an individual may be followed by the weeping of disheartened and grief-stricken relatives at the bedside, cellular death has only partly occurred. In warm weather, as on a mild mid-summer day, cellular life may continue for hours after somatic death—just as well as it would in case of occlusion of a nutrient vessel. More especially is this the case in sudden death.

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[2] From σῶμα—the body, meaning corporal.

The distinction between somatic and cellular death is one of the utmost importance, and should always be in the mind of the physician. It explains the resuscitation of dead persons. There is a case on record of a man lying in the sunshine at the bottom of a small, quiet, shallow stream for fully half an hour before he was taken out and efforts made at resuscitation, which proved successful at the end of several hours' unremitting labor.

Dr. Jerome Walker, of Brooklyn, was once called to attend a child suffering with diphtheria. It died while he was present. Consciousness was gone, the heart and lungs had ceased to act, the pupils were dilated, and, in fact, the child was a corpse. He tarried for a moment, and then left for his office, whence he returned with a Faradic battery. This he applied over the pneumogastric nerves and chest muscles. Fully twenty minutes had elapsed since the death of the child and the beginning of the electrical application. After a while the doctor's efforts were crowned with success, for there were a few gasps and a flicker of the heart, but the officious and ignorant relatives compelled him to desist, and the child passed away into complete cellular death.

Dr. Armor's Case of Resuscitation.

Probably one of the most remarkable of this class of cases is one of the late erudite and philosophic Dean of the Long Island College Hospital, Professor Samuel G. Armor. It was considered of such great importance by Professor Austin Flint, Jr., that he urgently requested that it be reported in full. It is well worth recording. I had it more than once from Dr. Armor's own lips. The patient was a well-to-do man, with wife and children. He had purchased a pain-relieving remedy from a traveling quack. Its basis was cannabis indica, or Indian hemp. He swallowed an overdose, taking it in drams instead of drops. In time, he developed all the symptoms of narcotic poisoning. In spite of all efforts on the part of the attending physician, he died. The grief-stricken wife and children wept at the bedside of the dead man. Dr. Armor was present; at that time he was Professor of Physiology in one of the Western schools. At last all left the death chamber except Dr. Armor and a negro attendant. Looking out of the window, the doctor mused for some time over the sad ending of his friend and benefactor, for such he had been, and came to the philosophic and scientific conclusion that his friend was somatically dead, to be sure, but that the cellular life must be active, for the room was warm. He thought that if the respiratory and circulatory functions could be maintained till enough of the poison had been eliminated by the cellular activity, the patient might still survive. Dr. Armor stated to me that, if required, he could solemnly swear that the shortest possible time that could have elapsed from the time death was declared until he had concluded to make efforts at resuscitation "was at least one hour!"

In this estimate he allowed for all the circumstances that might cause time to be overestimated, and felt certain, in his own mind, that he had fixed the time at less than it had actually been. Bottles of hot water were applied to the limbs; hot water, red pepper and whisky were injected into the bowel, and some also forced into the stomach. Artificial respiration was begun. When the doctor tired, the negro relieved him, and so they alternated. A stethoscope was occasionally employed to detect a possible heart flutter. All was of no avail. The body continued lifeless after two hours' effort. Hope had fled. The negro, however, continued while the doctor rested. The desire to save his friend, if possible, and the scientific aspects of the question that had been raised caused a renewed attempt. More injections were given and more hot bottles were applied. More than three hours had lapsed, and again was the attempt abandoned and once more vigorously made. After nearly four hours' hard work, and when about to desist for the third time, Dr. Armor thought he detected a slight movement of the lips. Soon again he was quite positive he saw it. Again he noticed it after a long interval, and then was certain of returning life. The stethoscope discovered an occasional slight muffled sound over the heart. More injections were given, and efforts at artificial respiration were redoubled. At last the gasps became pronounced, the heart beats more frequent, the respirations deeper and more regular, until eventually respiration and circulation were re-established, but at a slow rate. Consciousness was not regained for hours, but eventually it returned. Dr. Armor's description of his own feelings and those of the family and the negro at this time may be better imagined than they can be told. The patient was alive and well over a score of years afterwards; in fact, he was alive and well but a few years ago, and prominently interested and well known in New England financial and banking circles.

These cases teach the difference between somatic and cellular death, and demonstrate that when "life" is extinguished by a sudden interruption of the functions of the brain, heart, and lungs, without any organic[3] change, there is hope for recovery if proper efforts are made and persevered in, for hours, if necessary.

Functional Death.

The intelligent student and practitioner of medicine will always bear in mind the distinction between these two kinds of death. Just as we have so called functional diseases which are not accompanied by any known or detectable lesions of structure, so may we also have functional somatic death without structural lesion. In all such cases it should be our duty as physicians to attempt the return of "life" until there is undoubted evidence of cellular death; for instance, rigor mortis[4] would seem to be a reliable sign, judging from the present state of our knowledge on the subject, though coming investigation may show that even this is not necessarily a positive death accompaniment.

Importance of the Nervous System.

For the maintenance of life, the integrity of the nervous system, or at least of some of its parts, is absolutely essential. This is because it is the great controlling mechanism of the body. The nutrition of the body cells depends upon the proper working of a telegraph system that informs places of supply of the amount and character of the wants of these

[3] Pertaining to an organ. Organic changes are changes in structure.

[4] The stiffness of death.

communities. Then the freight lines are set in operation, and the required commodities are properly delivered in time to be utilized. In an analogous manner does the nervous system at once set about to promptly send the requisite materials to the cell districts that make the demand, and these are conveyed by the great freight line called the circulation.

How We Get Hungry.

We studied reflex action in a preceding chapter, and became acquainted with several clear illustrations of its principles—now let us apply it to cell nutrition. It is interesting to know how we get hungry. The explanation is easy. As has already been said, all cells are like individuals, or animals, or even plants for that matter, as regards their common peculiarities, i. e., they live, and to do so must ingest, egest, work and grow, as well as reproduce themselves. This is characteristic of the little ameba and protameba, a plant, any animal, or man; there is no difference but that of degree. Man is very complex in the number of his component parts, various functions, and numerous connections. Some of his cells are more susceptible than others. One feels the deprivation of food more than another. We might even say that some terminal nerve fibrils are more sensitive to the food requirements of cells than are others. However this may be, the fact remains that we are continually laboring, millions of our component cells being active during sleep. Our food supply is periodic, usually taking place three times in twenty-four hours. The want of food produces the sensation of hunger, and this consists of an empty, retracted (drawn) feeling in the stomach, a freer secretion of saliva, and a desire (appetite) for food. The cells of the stomach and gut are very active during a meal in the secretion of juices that change the food by chemic action and prepare it for absorption. Then the cells absorb this changed food and pass it through them by a process of osmosis to the nearest capillary vessels or lymphatics, as the case may be, depending upon the kind of food. A certain time after the conclusion of the meal, the work of the gastro-intestinal cells comes to an end—they rest. Being more sensitive to hunger than the other cells, they are among the first to experience the absence of food. Information of this fact is carried by the nerves to the proper nerve cells. They send out an impulse to the muscles of the stomach and intestines to contract, which they do, and thus compress the gas still remaining in the digestive tube. The cells of the tract, being very active, and being hungry, rapidly absorb the gas for want of something better. In this way all the gas in time becomes absorbed, and the stomach and intestines eventually are firmly contracted. If this continues because of the absence of food, as in starvation, the contraction of the muscles of the digestive tract becomes so marked that the blood vessels of the stomach and gut are compressed, the current of blood through them is impeded, the nerve fibres that carry the message of hunger from the suffering cells are benumbed, and at last the nerve cells no longer are informed of the plight of the stomach and intestinal cells. By this time the other cells of the body have also suffered from hunger, and like the stomach and intestinal cells, they, too, absorb whatever is near them. The fat that is stored up in the tissues, being practically inert, soon begins to serve as food (force-producing food) for the neighboring cells, and continues to do so till it is all gone and used. If the intelligence of the body that is suffering be not sufficient to understand the cause of its distress at this stage, the body becomes still weaker than it already is, the cells continue working as well and as long as they can endure until, eventually, they disintegrate and undergo chemic decomposition, during and subsequent to which the body dies and putrefies. This is death from starvation, and in all such instances there is no fat found anywhere in the body, the tissues are firm and dense because of the small amount of water they contain, and the digestive tract is contracted to its smallest calibre, and contains no gas.

Cell Breathing.

Another part of nutrition relates to the supply of oxygen. Cells are minute pieces of protoplasmic substance requiring food for sustenance and oxygen for respiration. These are supplied by blood. Besides performing the common function of maintenance, cells perform special kinds of work, causing metabolism and waste. The latter is carried off by the veins and lymphatics. The myriads of cells composing our bodies are related to one another and form a complete whole through the vascular apparatus and nervous system. There is a demand by the cells for food and oxygen, and the supply is regulated by means of the nervous system. So nicely is this relation between supply and demand preserved that a balance is only possible by a more or less shifting of the centre of equilibrium. This is, however, truer of the oxygenic than of the food supply. Just as an individual may exist for an unusual period without much food or none at all, so it is with the living cell. Yet no living man, woman, or child can exist for more than a few minutes, at most, without oxygen, and even so it is with the individual cell. Increased activity makes our respiration number more per minute because of the necessity of a greater proportion of oxygen. Diminished activity as in peaceful slumber, reduces the required amount to a minimum, and hence the slower and shallower breathing. Each living cell has exactly similar requirements. If increased cellular activity is limited to a circumscribed district of moderate size and importance, there is reflexly an increase in the calibre of the involved and adjacent blood-vessels and a quickening of the blood-currents, thus increasing the oxygenic supply. Should, however, the increased activity of tissues (cells) be sufficiently extensive or decided, or in so important a part, that the extra supply of oxygen is too great a drain on the general body supply, then it is absolutely essential that more must be admitted to the body in a given time than is normally the case, and we have, as a consequence, increase in the depth and number of respirations. This is illustrated, first, in the local hyperemia resulting from friction, foreign bodies in the eye, boils, and various local inflammations and hyperemias, when there is no increase in the number and depth of respirations; and second, in extensive burns, inflammations, and hyperemias, or when these are less extensive but in organs of serious significance, as the kidneys, lungs, liver, or brain, when increased breathing is the concomitant.

Our body cells get just enough oxygen to meet their demand—no more, no less. When a small or moderate increase is required, it is supplied by vascular dilation and determination from the general supply without general disturbance; but if a large quantity is needed, that is, more than the rest of the body can spare, the respiratory centres are called upon to add to the general supply by increasing the respirations in depth and number.[5]

[5] **Immunity in Disease. A. H. P. Leuf, M.D. New England Medical Monthly, December 15, 1886, pp. 98 and 99.**

CHAPTER VI.

CELL PHYSIOLOGY.

The functions of cells are of two kinds; those which relate to maintenance (including reproduction) and those which relate to special work. The same is true of all organisms, including man. In the lowest forms of life, as in the ameba and protameba, all work seems to consist of what is known sometimes as the animal function, i. e., the labor of maintenance (including reproduction). As we ascend higher in the scale of life, we notice that special functions, aside from the purely animal, show themselves. The special functions have culminated in man. By far the greater part of our energies are, or appear to be, spent in special work not essential either to our existence or the propagation of our kind. Some cells perform almost nothing but common work, while others do mostly special work, only a small part of the time being devoted to maintenance and reproduction. In the normal body, the connective tissue cell actually does little else than common work, all its special work being passive, i. e., framework or support, or the holding of other cells in place. It is, however, the special duty of this cell, under conditions which will soon be considered, to participate in some of the most active and potential processes that ever take place in organized bodies. High grade cells, such as those of the brain or liver, do a great deal of special work, in fact most of the time is spent in the elaboration of force and material more directly essential to other parts. Suppose a man does a given amount of work, he will require a given amount of food. If he increases his work he must increase his food. Supply must be equal to demand. Now why is this? The cell explains it. A man gets hungry because the many millions of cells that make up his body require food and clamor for it. The fine adjustments of the different parts of the body already mentioned make this much felt need manifest by the sensation of hunger and thirst.

The actions that take place in cells are due to chemic changes, and that means a destruction of the composition of part of the cells, and the necessity of a renewal of the part destroyed. Shoot a ball out of a revolver, and the composition of the powder has undergone a change. To send out another ball, it is absolutely essential that more powder should be added. Expend force through the agency of a steam engine, and there is a change in the composition of the fuel and a loss of water converted into steam, which is also lost. More or both must be added or soon all the material will be spent and the machine come to naught as regards ability to labor.

Regeneration of Cells.

The living cells of the living body, therefore, are constantly at work, ever active, are always undergoing partial decomposition and regeneration, and for this purpose require constant, or at least frequent, supplies of food and fuel, which is incorporated within themselves to be changed in the production of special work, and eliminated by the proper channels in the various instances.

When cells are compelled to labor unusually hard, they are over-active, and it is said to be a hyper-activity.[1] Increased work requires increased food supply. Increased functional activity, hyper-activity, causes an increased supply of blood, which conveys the food or fuel of the cells. One evidence of this increased blood supply consists in the redness of the part due to the larger amount of the red blood. Another is in the increased warmth due to the free supply of the warm blood, the increased chemic changes in the affected territory, and the increased friction in the vessels from the greater flow of blood. There may be soreness or pain, not so much from pressure upon nerves from the slight enlargement of the parts, as from the inability to remove the effete material of the cells as rapidly as it is formed, thus poisoning and irritating the adacent nerves. Increased egestion is consistent with the increased ingestion and metabolism[2] that go with increased functional activity of a part and its greater food or blood supply. Under these circumstances, the cells

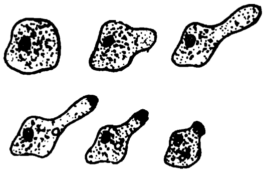
[1] From *ὑπέρ*—over, and activity.

[2] From *μεταβολή*—change.

live quicker and, if kept up, live a shorter life, just like the "fast young man" who "burns the candle at both ends." This rapid and excessive action, if continued, leads to changed conditions of life, the parts become uncomfortable, they are no longer at ease, but they are dis—eased.

Ameboid Movement.

The movements of cells, as seen in the extension and retraction of the pseudo-pod of a leucocyte, or ameba, is not accomplished without destructive changes. Every motion of a leucocyte or an ameba is costly in the sense that it is only possible as the result of a chemic change—a combustion. If carefully studied under the microscope on a warm stage, the pseudo-pod is seen to slowly extend from the body until it reaches its limit of extension. With its retraction, there is to be seen at its distal end a granular disintegration and the formation of a vacuole,[3] or air sac, at the juncture of the process with the cell. As the process grows smaller and smaller, its distal end becomes more and more granular, and the vacuole gets larger and moves further away from the base of the disappearing process. This shows that the mass of the ameba, or leucocyte, loses substance during the retraction, or contraction of the process. In fact, it is largely a destruction of the process. On the other hand, the volume is increased during the expansion or extension of the pseudo-pod. This all teaches that expansion is an active generative process, while contraction is relatively passive or degenerative. Muscle cells, as observed through the microscope in the living worm, have revealed analogous phenomena.



Ameboid Movement. Representing the extrusion and retraction of the pseudopod, with the entailed granular destruction of protoplasm and the formation of gas

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[3] From *vacuum*—an empty space.

Cell Reproduction.

The reproduction of cells is interesting and occurs in several ways. Virchow is the original champion of the idea that every cell originates directly from a preëxisting cell. Cells proliferate in the same manner as do the protameba and the ameba, i. e., by a budding or gemmation[4] process, consisting in the sending out of pseudo-pods which grow larger at the distal end, while the connecting protoplasm becomes smaller and smaller until at last it is a mere filament that is parted by any slight accidental disturbance, thus giving rise to a new cell. Leucocytes may be seen doing this if carefully observed on a warm stage. Different cells which are not restricted give birth to others in much the same way. Instead, however, of sending out offshoots that grow and become detached, they divide into halves, and a little later each half is about as large as the parent cell. Then division again occurs. In most nucleated cells, division begins in the nucleus, though sometimes it begins in the protoplasm, and at times the nucleus does not divide at all. In the giant cells, however, the nuclei proliferate while the cell protoplasm does not, but instead continues to grow larger.

A still more interesting mode of cell generation is the endogenous[5] or vacuolation process. In this variety there is a firm encapsulating wall which extends pari passu with the growth of the contained cell. Eventually the cell divides and subdivides into daughter cells, as they are often called. Meanwhile the capsule may have grown to several times its original dimensions for the accommodation of the young cell brood. The last stage of the process consists in a rupture of the cell wall and the extrusion of the young cells. Each of these again in turn gives rise to other cells by the endogenous method. This kind of cell growth is typified in cartilage. The term vacuolation, which is also given to this process of proliferation, is held by Green and others as not being typified in cartilage. They say that the cartilage cell simply multiplies by division within a capsule. Dr. Klein, of London, has described vacuolation as the formation of a vacuole in a preexisting cell, which causes a distention of the protoplasm and a dislocation of the nucleus. At last only a small rim of cell protoplasm is left outside of a large chamber. The nucleus is to be seen somewhere in this rim. Buds are thrown out from this distended protoplasm into the vacuole, and eventually become detached and form loose cells.

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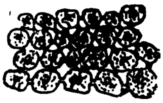
[4] From *gerere*—to produce.

[5] From ενδον—within, and γενναω—I engender.

Proliferating Cells.

Cell proliferation is general in all tissues during embryonic life and in some tissues for a certain time thereafter, while it falls to the lot of other cells never to lose the power of proliferation. Such are the connective tissue cells. Of those that do not proliferate after development is completed, the liver cells may be cited as notable examples, and also nerve cells.

Some cells absorb pigment granules, and are then said to be pigment cells. A black pigment, called melanin,[6] is absorbed by some cells in certain forms of morbid growths, as, for instance, sarcoma, giving rise to what is appropriately called melanotic-sarcoma.



Diagramatic Representation of the Protoplasmic Union of Cells.

Cells are more or less mortared together by what is called inter-cellular cement substance. This is secreted by the cells themselves, and helps fill interstices as well as strengthen the protoplasmic union of cells.

Length of Cell Life.

Though we live long lives, cells have a short existence. Cell life may be estimated at the epithelial surfaces of the body, as for instance, the mucous membranes, skin, nails and hair. The exfoliation of the cutaneous cells, especially when the flesh brush is used and in cases of dandruff, is one example; the passage of epithelial cells with the feces, urine, spittle and nasal mucous is another; and then we also have the growth of the hairs and nails. Berthold, the Göttingen physiologist, showed that a nail cell lives but four months in summer and five months in winter. Most cells live even a shorter time. Nerve cells have the greatest longevity.

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[6] From μελας—black.

The Ovule and Its Growth.

The ovule,[7] which is the origin of all animal beings, proliferates by division and subdivision until many smaller cells are crowded in layers against a firm encapsulating wall, with a fluid centre. Subsequently these cells divide into two layers, and eventually a third or intermediate one is formed.

These are called blastodermic[8] layers, and are known from within outwards as the endo-blast,[9] meso-blast[10] and ecto-blast.[11] These three layers form the inner and outer integuments of the body and intermediate structures. They are also called ento-derm, meso-derm and ecto-derm. These layers form the body tissues as follows:

The entoderm or endoblast gives origin to the epithelial lining of the digestive and respiratory apparatuses, and of the bladder and prostatic urethra in the male, together with the liver, pancreas, and the glands connected with the respiratory tract.

The mesoderm or mesoblast gives origin to the endothelium, fibrous tissues, involuntary muscles including the heart, ligaments, cartilage, bone, blood and lymph vessels and cells, spleen, and the genito-urinary apparatus except the bladder and urethra.

The ectoderm or ectoblast gives origin to the hair and its adnexa, the epithelium of the nose and mouth and their openings, the salivary glands and dental anamel, the crystalline lens and retina, the mammary gland, the membranous labyrinth, and the whole nervous system.

The cells comprising these layers are called embryonic[12] cells. They have no other characteristic than that they are small and non-nucleated. Many such cells are, late in life, characteristic of morbid[13] growths, of which the origin, according to some authorities, is very plausibly assigned to defects of the blastoderm.

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[7] The diminutive of *ovum*—an egg.

[8] From *βλαστος*—germ, and *δερμα*—skin.

[9] From *ενδον*—within, and *βλαστος*—germ.

[10] From *μεσος*—middle, and *βλαστος*—germ.

[1] From *εκτος*—outside, and *βλαστος*—germ.

[12] From *εν*—in, into, or within, and *βρυω*—I grow.

Provision Against Self Poisoning.

There is also a provision against suffering from natural poisons in our bodies. By natural poisons are meant such as are normally found in the body, as, for instance, carbonic oxide. These are eliminated by the circulating blood almost as soon as formed. But there are other poisons, usually of animal origin, which often gain entrance to the body and endanger life. Against such an invasion of our citadel there is also provision, and this is in the lymphatic apparatus. It is the tendency of lymphatic glands to intercept such poisons as cancer or syphilis and hold them until they become harmless or until the irritation of their presence excites destructive changes in the glands, thus destroying and lessening their inhibitory function, and permitting the virus to enter the blood current and the poisoning to become general. The following quotation from a paper by the author is to the point:[14]

"We all know from the results of investigation in the physiologic and pathologic laboratory, as well as clinic experience, that the blood is the body's distributor of food and air in its passage from the heart, while on its return it renovates the tissues by the abstraction of those impurities that are the natural result of physiologic metamorphosis. The lymphatics, on the contrary, among other things, perform an interceptive function in preventing or retarding the entrance into the circulating blood of these deleterious substances for the elimination of which there appears to be no special provision. Thus, although carbonic acid and urea are very poisonous, they enter the blood to be promptly excreted, the one by the lungs and the other by the kidneys; there is a special provision for their elimination, as they are a normal, constant and necessary product. Contrariwise, the virus of carcinoma is not the outcome of normal, constant and necessary physiologic activity, but the result of changes that are abnormal, inconsistent and decidedly unnecessary, and hence has not provided for it a special and normal eliminative organ. If it once enters the blood, it will remain and spread disaster. It only gets there insidiously. The blood does not take it up. Lymphatic vessels which ramify throughout the body, and lymph spaces existing in nearly all the tissues, absorb this product of unusual and abnormal metamorphosis, and conduct it to the first set of lymphatic glands. Here it is retained as long as the gland is capable of holding it, and when this retentive function becomes inefficient, the poison passes into the blood, and the general infection of the individual is the immediate and inevitable result."

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[13] From *morbus*—disease.

[14] On the Eradication of Syphilis during the First Stage by Surgical Means. New York Medical Journal, July 11, 1885, p. 36.

Cell Adaptability.

Another peculiarity of cell action is adaptability. It is possible for us to become accustomed to change of climate, in fact it is well known that even in one man there may be found marked resisting power alike against the frigid winter of the extreme north and the torrid summer of equatorial climes. This is due to cell action and reaction. Again, many live in healthful homes and would die in a foul environment, and, on the other hand, others live and do hard work to old age in surroundings that almost reek with dirt and disease. Another quotation from a paper by the author is here also to the point:[15]

"In all our large cities we have sections called slums, where the inhabitants are vile in their foulness and where it is impossible ever to find air except it contains enormous per centages of carbonic acid, germs, and malodorous effluvia from all kinds of putrescent decomposition. On the other hand, in the same cities may be found the exact counterpart. In each section are to be found human beings of all ages and in all stages of health. Transpose the most healthy of both sections, and while most of those from the salubrious districts will languish or perish in the slums, those from the latter will all thrive by the change to healthier districts. Those of the first lot who live do so because of their greater vitality and adaptability as compared with those who die. It is, in fact, an instance of survival of the fittest, and is a part of natural selection. The second lot, being placed under more favorable circumstances than before, thrive all the better, and are more capable for either good or bad than before. Even some of these, after long enough sojourn in their new environment, could not go back whence they came originally without risk to health or even life. Thus we have llustrated the law of adaptability or natural selection. It varies in different individuals, and in the same person under changed conditions, and at various times."

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[15] Immunity in Disease. New England Medical Monthly, December, 1886, p. 99.

This immutable law affects all nature. We cannot escape it. The power of adaptability differs with individuals. Just as one is strong and another weak, or one bright and another stupid, or one quick and another slow, or one excitable and another phlegmatic, or one naturally good, like Oliver Twist, or naturally bad, like Bill Sykes, so also do we find some persons whose susceptibility is so great that they are predisposed to all kinds of disease, while, on the other hand, there are some whom it seems nothing can affect but violence, dissipation and natural decay.

Function of the Blood Cells.

According to the latest researches in physiology, it appears that the plasma of the blood is merely a vehicle for the carriage of red and white cells, so that while the former are the lungs of the tissue cells for which they virtually carry on respiration, the latter supply the ultimately prepared food, called nuclein, for final assimilation. The leucocyte swells itself up with food products in the plasma, called proteids, which it absorbs by osmosis, and converts into nuclein through the vitalizing influence of its nuclei. Finally the distended leucocyte bursts and its nuclei form other white cells. The nuclein thus liberated by the bursted cell is carried through the capillary wall with some plasma to the adjoining cell brood, which absorbs what it requires and lets the remainder go, at the same time discharging its own effete material and special product. Thus the liver cells appropriate from the surrounding nuclein its pabulum, and from the red cell its oxygen, returning carbonic oxide to the red cell, some effete material and special products, as glycogen, also to the blood current, another product (bile) to the bile ducts, and certain poisonous substances to the lymphatics.

The Conservators of the Body.

The conservators of the organism are, therefore, the lymphatics and their glands. They intercept and, where possible, destroy deleterious material. They also increase the number of leucocytes when necessary, and in this are aided by some or all of the ductless glands, thus supplying an army to oppose the invading foe, as will appear in the succeeding chapters.

The Enzymes.

Later researches have made clear the presence in the blood of catalytic[16] substances called enzymes,[17] acting merely, as all such bodies do, by virtue of their presence, and undergoing no change themselves. They are a product of leucocyte activity, though their genesis is not yet thoroughly known. But many enzymes have been obtained. It is supposed, for instance, that a certain enzyme (unknown) antagonizes the poison of measles, at first combating and then overcoming it. These enzymes stand guard before the body cells, keeping out (say by coagulation, dehydration or oxidation) such as are harmful or have no food quality, but admitting those which are needful. Thus they are the means of making special needed parts of the passing blood current available for use by the cell at the same time that they, or others like them, dissolve obnoxious material in the cell for its elimination via the passing blood or through the lymph channels.

Increased use of any of these enzymes begets their more abundant production, thus accounting for the gradually increasing capacity of individuals to absorb poisonous substances by constant use and slow augmentation of dose. The tolerance of arsenic, morphine, alcohol, tobacco, and the many other substances can be cited in illustration. Acclimatization[18] is similarly explainable. So also the immunity acquired by an attack of most of the zymotic[19] and infectious[20] diseases.

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[16] From *καταλύειν*—to dissolve.

[17] From *ἐν*—in, and *ζύμη*—leaven.

[18] From *ad*—to, and *clima*—climate.

[19] From *ζύμωσις*—fermentation.

[20] From *inficere*—to put in, or corrupt.

CHAPTER VII.

CELL PATHOLOGY.

It is well to remember that it is the rule for most cells no longer to proliferate after the body has attained its full development. Sometimes there are a few such changes as life advances. As a rule, though, it is only when the normal relations and functions are disturbed that proliferation occurs. We have learned that increased functional activity leads to increased supply of blood—hyperemia. Just as an individual will not be able to stand a certain amount of overwork, so will a cell or a series of cells likewise resist, but only to a certain extent, such a strain. Cells will bear stimulation, but not irritation. The former is excitation within physiologic limits, and the latter is excitation beyond these limits. Now, what is the effect of irritation if stimulation causes undue hyperemia? Simply markedly increased hyperemia, and eventually changes brought about by cell reactions that have no place in normal physiology, and, therefore, become abnormal or pathologic.[1] Under such circumstances the higher tissues atrophy, die and disintegrate, and the lower tissues proliferate. An irritation sufficiently severe and prolonged will cause destruction of the higher cells and tissues. That is all, and needs no further consideration at present. What concerns us more now is the action of the lower tissues.

Effect of Cell Irritation.

The cells of the whole connective tissue group become exceedingly active and proliferate when sufficiently irritated. Previous to this there usually occur other phenomena. What these are is best seen in the web of the frog's foot and its mesentery. The part to be studied is fixed under the objective of a microscope at a temperature of from 70 to 80 degrees F. It may be irritated with a sharp point or a drop of acid. The primary effect is upon the vessels. At first there is a momentary contraction or spasm of the capillaries, which is promptly succeeded by a dilatation. The blood flows more rapidly through the widening calibre of the vessels, with the erythrocytes rushing along the centre of the channel, while the leucocytes linger lazily along the sides, adhering to the walls, where they lengthen in the direction of the current and turn over full length and again creep along. A little later other changes take place about which there is a difference of opinion among even the best observers.

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[1] From παθος—disease, and λογος—a discourse.

Diapedesis.

Some claim that the leucocytes pass through openings or stomata[2] in the side of the capillaries between the adjacent edges or corners of the cells forming the vessel walls. They have seen what they believe to be a peeping through of a process or pseudopod of a leucocyte into the perivascular[3] tissue, like so many people looking out of the windows of a row of houses on a summer's day and wishing each other a kind good morning, or like a criminal about to steal out of a prison and create havoc in the adjacent district. However this may be, the leucocytes are supposed to gradually draw themselves through these small openings by means of their ameboid[4] movements and begin wandering or tramping around, paying their respects to neighboring connective tissue cells. There are also others who believe that the white blood cells at times actually pass through the body of the cell of the capillary barring its way to the adjacent tissues, and they claim to have seen it. While this is actually taking place, or supposed to be going on, there is really a transudation of the plasma of the blood into the perivascular tissue. It has the power to coagulate in the tissues as it has when it leaves the vessels for any other place. It is also known as lymph, and because it has something to do with healing, or was supposed to have, it has been called plastic lymph and plastic exudate. This overtakes the nomadic leucocyte and the adjacent fixed cells like a local flood or inundation. It is abundant pabulum for all the cells, and thus enables them to feed sufficiently during the excessive labor consequent upon the irritation to which they have been subjected.

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[2] From στομα—mouth.

[3] From περι—around.

[4] From αμειβα— change, and ειδος—like.

No one denies that the irritation which is sufficient to cause such sudden spasm of the capillaries, and then their partial paralysis, is not wholly without effect upon the functions of the cells composing the capillary walls. Some observers claim or have claimed, that the cells of the vessel walls begin an active proliferation, which may extend into the calibre of the vessels, or externally, or both ways at the same point. They also believe that, while leucocytes may occasionally diapedese,[5] it is exceptional, and that what has generally been looked upon as a diapedesis of leucocytes is nothing more nor less than the budding from the vessel wall, and that those wandering cells that leave the vessels are not leucocytes, but recent offshoots, detached buds from the irritated and proliferated capillary cell wall. However this may really be, it is not an accepted fact, and the unfortunate student must remember two or more explanations of a part of this important process until his diploma is actually his own, when he may take sides if he choose, or wait philosophically until the oft-lauded happy medium between two extremes has been definitely determined. Probably all sides are right in saying that these different things occur, and are wrong in denying all truth to the other sides.

We have now considered, in justice to all, and allowed that the capillaries contract spasmodically for a moment; that they become dilated and partly paralyzed; that there is at first a quickening of the blood current; that the erythrocytes keep closely huddled together in a rushing mass along the centre of the capillary stream; that the leucocytes linger affectionately along the capillary wall, hugging it most of the time, and usually only letting go when forced to do so by a rude erythrocyte that has wandered off from the centre of the stream; that there is an exudation of plasma and a diapedesis of leucocytes into the perivascular tissue; that there is an active proliferation of the vessel walls that causes the throwing off of new cells into the surrounding tissues; that these newly formed cells have marked and active ameboid movements.

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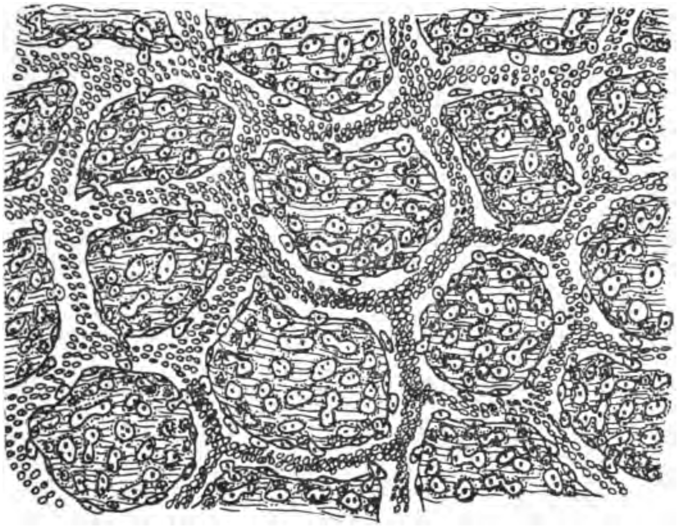
[5] From διά--through, and πηδᾶν—to leap.

Proliferation.

The next thing noticed is a slowing, and perhaps eventual stagnation, of the blood current. The wandering cells having ameboid movements induce the same in the fixed connective tissue cells with which they come in contact, or else the original irritation was in itself sufficient cause, which it may often be rational to believe. Certain it is, that these fixed cells do proliferate and become wandering cells. The connection between them is destroyed. The plastic exudate serves as pabulum for the newly proliferated and wandering cells. The proliferation may continue indefinitely until all the exudate has been absorbed and converted into living, active ameboid bodies. Additional effusion of plasma and lymph may continually take place to supply the demand and to aid in preventing the encroachment of the wandering cells into normal structures.



Early Stage of Inflammation. **Diagramatic representation of diapedesis, dilated capillaries, stagnant circulation, and proliferating cells.**

Inflammation.[6]

The increased bulk occasioned by the dilatation of the vessels, the exudation of plasma, and the rapid growth of new cells, causes swelling of the parts involved and of neighboring districts. When near the surface of the body, this is easily appreciated by the touch and sight; the consequent pressure and tension upon the nerves, gives rise to more or less pain; the increased vascularity, causes a varying degree of redness if near the surface; while the increased functional activity, in fact, pathologic activity, gives rise to heat from more active metabolism and consequent chemic changes, increased friction and additional supply of warm blood. Thus we have an easy explanation of what were called the four cardinal signs of this process, i. e., heat, pain, redness and swelling.

Resolution.

If the process goes no further, as in the case of the frog's web or mesentary, the vessels resume their tone and normal action; the remainder of the exuded plasma is absorbed, many of the wandering cells enter the blood current and are in some way disposed of, while others remain in the tissues and undergo certain changes. This is termed resolution. The changes which those cells undergo that remain in the tissues are as follows: At first they are round or irregularly spheroid; they become ovoid and oblong; at last they assume a fusiform or spindle shape; soon the pointed extremeties elongate, and may even divide and form fine filaments, which unite with others from neighboring cells. In this way the connective tissue is once more restored, but it is different from the normal variety in that it is more compact and has the property of contraction.

This new connective tissue is technically known as cicatricial or scar tissue. If it is on the surface of the body, it is commonly called a scar, and technically designated as a cicatrix.[7] Whoever has observed a scar of the skin, will have noticed that if it has been two inches in length as soon as the wound causing it has healed, it may measure only one inch at the end of one or two years. Subsequent years will show additional contraction. In the case of severe burns, particularly of the face and neck, the resulting cicatrices contract so very much that they sometimes pull the chin down upon the breastbone New scar or cicatricial tissue, wherever formed, has more or less of the quality of contraction. If anything is caught within a cicatrix or grows there, it will get a severe squeezing in the course of a year or two, and if it is a tender and sensitive structure, as, for instance, a nerve, it will cause much pain until dissected out from the grasp of its tight surroundings. This quality of contraction in scar tissue it is important to bear well in mind.

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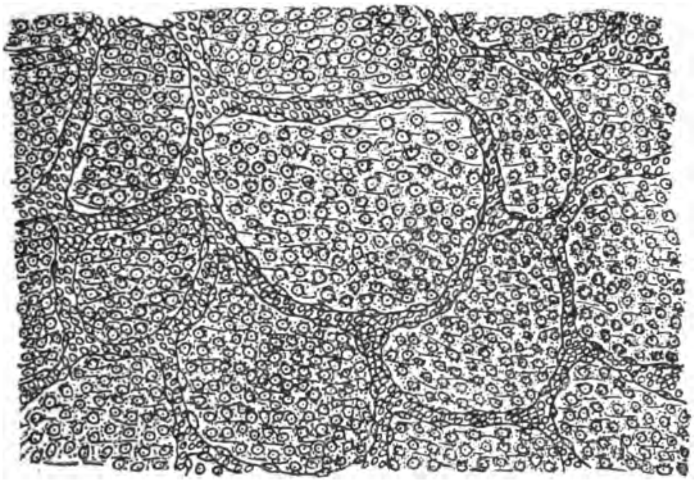
[6] From *inflammatio*—a burning.

[7] From *cæcare*—to conceal, because it hides the wound.

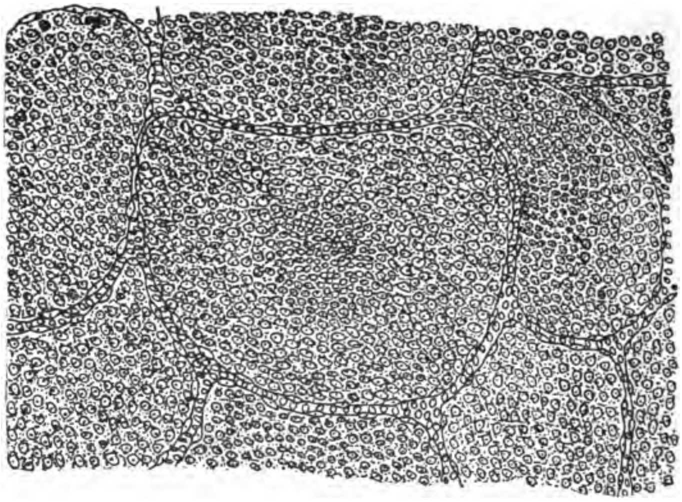
Suppuration.

Now, suppose resolution does not take place. What then? Instead of ending in resolution, the proliferating process may continue. If it does, it will add to the swelling and pain to a considerable extent, and also to the heat and redness. The new cells grow largely at the expense, and take the place, of the normal adjacent tissue. After a while the cells become so numerous that those which are oldest and most central



Later Stage of Inflammation. Intensification of the preceding, and almost total stoppage of circulation, with proliferation active. Abscess impending.

are farthest removed from the source of nutrition. They have absorbed all the exuded plasma within their vicinity, and are too far removed from the nearest blood vessels to imbibe nourishment at a distance. In consequence, they atrophy, degenerate and die. They then break down and form a semi-fluid mass, composed, to a large extent, of fat. Portions of normal tissue still remaining in the midst of the dead and dying cells also break down because their nutrient capillaries have been compressed by the new cell mass, and occluded by the proliferation of the cells of their own walls. This broken down semi-liquid cell mass constitutes pus.[8] Among the dead are living cells. Proliferation at the periphery of the new cell aggregation continues undisturbed, and also through to the inner border of living cells. When this point has been reached, we have a miniature abscess cavity.



Still Later Stage of Inflammation. Further intensification of the preceding; occlusion of capillaries from excessive cell proliferation, resulting ultimately in death from starvation, because pabulum has been cut off by compression. Abscess inevitable.

Abscess.

An abscess, therefore, is a collection of dead and living, newly formed and old cells and serous fluid, in a space formed by both broken down and normal tissue. In other words, it is a circumscribed collection of pus in an abnormal cavity. If pus formations have no distinct limitations, they are known as diffuse abscesses. On the other hand, the plastic lymph or plasma and the proliferating connective tissue cells formed at the periphery of the new cell accumulation, form scar-tissue, as already described, and prevent the further extension of the pus-forming or pyogenic[9] process.

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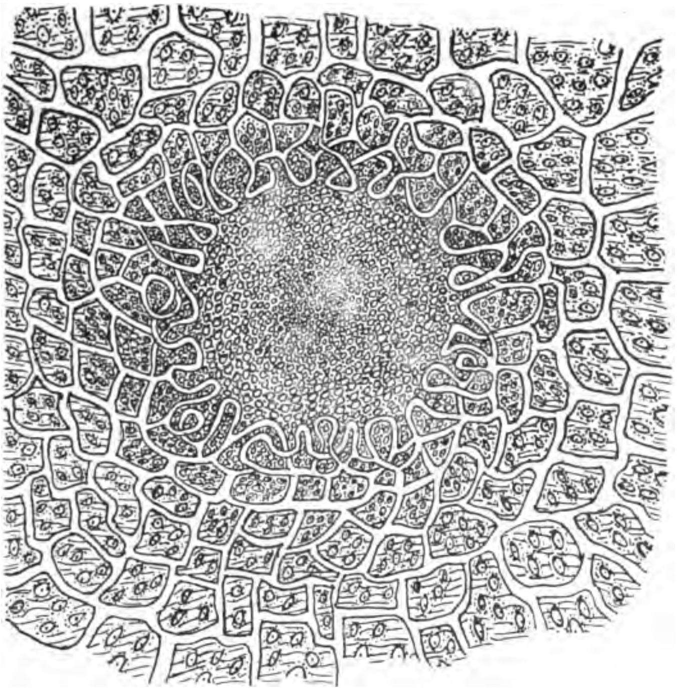
[8] From πυος and πυον—the matter of wounds and inflamed surfaces.



Final Inflammatory Change. Final outcome of the preceding; obliteration of capillaries and intervening tissue in centre because of over-crowding, and formation of vascular loops at the periphery of the field of destruction to effect absorption and repair, and to form a limiting secreting wall to guard against infection, and that causes a constant addition to the pus mass with consequent growth in the abscess. Abscess formed.

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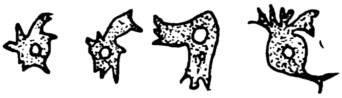
[9] From πυος and πυον—pus, and γενναω—I generate.

The Pyogenic Membrane.

This limiting wall may continue an active cell growth from its inner surface, thus causing a constant increase in the quantity of contained pus and a sustained distention of the wall or sac itself. When this limiting or pyogenic wall has been well organized and distended, and still continues in the generation of new cells, it is aptly called a pyogenic membrane. An abscess whose limiting wall is a pusforming membrane, steadily increases in size, and in doing so dilates its wall or sac, and this dilatation leads to additional growth, or thickening, or hypertrophy, as it is variously designated.

Abscess Ending in Resolution.

Such a pus sac or absess may even end in resolution. If it does, the pyogenic membrane ceases its excessive cell formation and adds to its inner surface those which still are being formed, and in this way encroaches upon the pus cavity. Some of the contained living healthy pus serves as pabulum for the growing cells of the abscess wall, as did the exuded plasma originally. Diminution of internal pressure permits the walls eventually to coalesce and unite. This completes the process. The former pus cavity or abscess is replaced by a plug of scar tissue. It is firm and hard to the touch. It feels tender to its owner. As the lump of scar tissue contracts, it becomes small, less painful and harder. At last it reaches its minimum, and may almost entirely disappear or remain as a well-marked nodule, depending upon the size of the original cavity and the amount of new tissue found necessary to fill the gap left by the pus.



Living Pus Cells. **Showing the changes in a living pus cell, similar to those of a leukocyte.**

Spontaneous Opening of An Abscess.

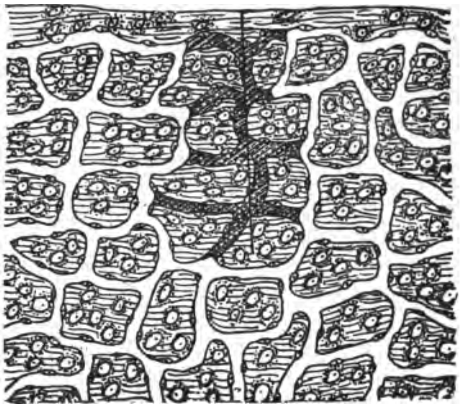
When such a closed abscess does not heal by resolution, it continues to grow. Its growth is always in the direction of least resistance, and that is almost always towards the surface of the body. Hence it is the rule for even the deepest-seated abscesses to eventually reach the integuments. The normal tissues are either pushed aside or compressed before it and absorbed. The same happens to the skin, and when it is so thin that it is no longer able to resist the pressure, it ruptures and there is an escape of pus. It is then we say that the abscess has opened spontaneously, or of its own accord. The surgeon anticipates nature by opening such cavities with a bistoury as soon as they are near enough to be safely accessible and positively identified. In this way many days of suffering are often saved, and sometimes even weeks. The strength of a patient may in this way be much conserved.

Healing of An Abscess.

The conditions of the healing of an abscess cavity are the same, whether it is opened with a knife or does so spontaneously. It should be evacuated of its contents, and the walls gently and continuously approximated from the deepest parts by firm and steady pressure, so as to encourage the union of its walls. To ensure the free discharge of pus, it is necessary that an unobstructed channel be provided, and this is called drainage, and may be accomplished with horse hair, silk or tubes of various kinds; in fact, any non-irritating substance that will extend from the deepest part of the sac through the opening. Free drainage and steady, even compression are of great importance in the treatment of abscess. If this is not sufficient, it is necessary to apply stimulating washes to the inner side of the pyogenic membrane or pus sac, or it may be necessary to scrape away the entire inner surface of the pyogenic sac with a sharp instrument, this procedure being called curetting. This causes a reaction, a quicker blood current and healthier cell formation. Healing takes place as by resolution, except that nearly all of the pus is drained away.

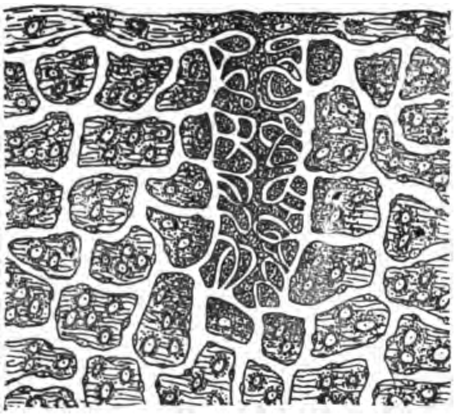
Healing of Wounds.

How do wounds heal? is the next question. Let us suppose a section through healthy tissue. All the capillary vessels that cross the cut district have been severed. After a little hemorrhage, their contained blood coagulates as far back as their nearest junction with some capillary vessels. There is, therefore, all along the wound's surface, a layer of cells that have been cut off from their usual blood supply because of severance of their nutrient capillaries and their occlusion by a plug of coagulated blood. These cells, from what has already been said, must either imbibe nutriment from a distance, i. e., from the nearest pervious capillaries, or, failing in that, starve to death. The fact is that those more nearly adjacent to the still pervious capillaries live, while those which are more immediately located on or near the wound's surface may die. Supposing now that the wounded surfaces, after having been cleaned and allowed to dry, are brought accurately together and held there with moderate pressure, either through the agency of adhesive straps, or sutures, or both combined. There will then be a dilatation of those capillaries nearest the wound's surface through which the collateral circulation takes place. We see here the similarity with the beginning of the process in the web or mesentery of the frog. The blood vessels behave in the same manner, and there is a diapedesis of leucocytes and an exudation of plasma. This is followed by an active cell proliferation. The newly-formed



Incised Wound with Coaptated Sides **(in diagram), the several capillaries being occluded with coagulated blood as far back as the nearest collateral channels.**

cells live at the expense of the exuded plasma and the old cells that lie upon and near the wound's surface. Soon the old and dying cells have given way to the new cell generation. Meanwhile vascular prolongations have crowded themselves forward from the marginal capillaries. These soon form loops which eventually inosculate freely with their fellows of the opposite side, and thus re-establish a firm continuity between the two sides of the wound. When this has been accomplished the active changes cease, vascularity diminishes, proliferation comes to a standstill, absorption becomes the main function, and the remaining plasma and unstable cells are absorbed, while the cells which remain undergo the previously described changes of cicatricial tissue formation, i. e., elongation, assumption of a fusiform shape, the growth of extended processes, and their union with similar ones of the neighboring cells. At first the scar is red from excessive vascularity, and frequently tender from pressure upon adjacent nerves. The diminishing vascularity renders the scar paler, and the contraction of the new tissue diminishes its size, thus increasing the firmness of the cicatrix and also reducing its vascularity by constricting its vessels.



Advanced Stage of the Preceding, showing the formation of vascular loops into the cell proliferating district caused by an incised wound.

Healing by Granulation.

The next question is as to what occurs if the wound's surfaces are not approximated, but are permitted to go as they like without any coaptation.[10] In such a case, healing simply takes place in exactly the same way as that just described and as given more fully in the healing of an abscess. There is this difference: There is a flow of newly-formed cells, serum and pus from the surface. The vascular loops already mentioned of course cannot inosculate with their fellows of the opposite side because of the intervening distance. They simply push forward and add loop upon loop connecting with other adjacent loops. They crowd forward pari passu with the advancing new cell growth to supply them with nourishment. The surplus cells are thrown off the surface as pus, while those which remain serve to eventually form a cicatrix. The surface of such a healing wound has a granular aspect, due to the new capillary loops and their superimposed cells. Such a surface is very properly called a granulating surface, and the individual papillae are known as granulations. Union occurring in this way is designated healing by granulation or healing by suppuration. Two granulating surfaces may be approximated at any time and held in opposition, with the result of causing their direct union. In such an instance, the vascular loops grow through their cell covering and inosculate with those of the opposite surface, and we have the same condition of affairs noted in the healing of a simple incised wound with surfaces coaptated from the beginning.

Covering of a Wound.

Should, on the other hand, the surfaces remain apart, the formation of granulations continues and at last fills the wound. As soon as granulation tissue has reached an epithelial surface, its growth comes to a standstill and is smoothed off by an outgrowth or overgrowth of epithelial cells from the normal epithelial periphery of the wound. When this covering of granulation tissue is completed, repair is at an end. The subsequent changes are the same as already mentioned, diminished vascularity, contraction of the scar, and resorption of superfluous cells and fluid.

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[10] From *co*—together, and *aptare*—to adapt.

Effect of Epithelium Upon Granulating Surfaces.

Epithelial cells in some way have the power to check the further growth of a granulating surface. On this account it is possible to engraft normal skin or mucous membrane upon a wound's surface after granulations have formed. Epithelial structures of all kinds and from various animals have the same property. Even epithelial scales sprinkled upon a granulating surface cause a rapid completion of the healing process. Bone, nerve, tendon and other tissues may also be grown together. The advantage in having an epithelial surface on a scar is that it either prevents or lessens subsequent contraction. This is especially true if only the integument is involved in the process of granulation.

Phagocytosis.

As has been already stated, the leukocyte has the power to antagonize foreign organisms by the rapid production of an organic substance at present called nuclein by some and protonuclein by others, or its formation of special enzymes acts as a chemic or physiologic antidote to the invaders. Besides this, the leukocyte has a phagocytic[11] (cell or germ killing) power which it exercises by capturing, enveloping and destroying the offensive invader. When the contact of foreign organisms (disease germs) with the granulating surface is prevented, as by antiseptic safeguards, or in subcutaneous processes, only enough leukocytes are usually formed to further the healing process; but when foreign organisms reach the field of action, the proliferation of leukocytes is increased, and the additional cells are placed upon the surface to meet the foreign foe, just as our citizens would assemble at the coast or frontier, as soldiers, to repel an invading enemy. This explains why granulating surfaces devoid of organisms complete the process of healing with a minimum amount of proliferation.

When disease organisms enter the body itself by any channel, whether by artificial or natural openings, i. e., the wound,

[11] From φαγείν—to eat, and κύτος—cell.

mouth, nose or skin, the proliferation of leukocytes is increased, so that they may destroy the invading organism by the generation of an unusual amount of protonuclein or nuclein or antitoxin or enzyme. This is the developing theory now; it is beautifully plausible and may stand the test of time, at least it is to be hoped so. Some of this product of the leukocyte is at present in the commercial market in liquid and tablet form under various names, the most prominent, and seemingly thus far the most successful, being the serum preparations from convalescent patients, immune animals and the yeast nuclein. But it will require years of experiment to positively prove their value and eliminate the possibility of coincidence.

CHAPTER VIII.

GENERAL PRINCIPLES.

A review of the preceding studies reveals that the body is a complex cell aggregation, characterized by the four essential qualities of living organisms, i. e., ingestion, work, egestion and reproduction. It differs from other organisms in degree only, being the most complex of all. The greatest differentiation exists in the nervous system, especially in the psychologic functions. The anatomic units, called cells, are simply minute pieces of protoplasm modified in form by environment and in function by evolution. The union of cells with their afferent and efferent vessels and controlling nerves constitute tissue, and a complete mass of this makes up an organ. All similar organs, such as bone, muscle or nerve, constitute a system (as the osseous, muscular and nervous), in which every organ does the same kind of work, but with different results; whereas a combination of dissimilar organs, such as the teeth, salivary glands, stomach and liver, which, although their functions are entirely dissimilar, thus necessarily performing varying duties, yet all tending to the same end (the conversion of food into blood), form an apparatus. Yet all these organs and systems and apparatuses are united to the one end of constituting a living individual of larger scope than any of its parts.

Cell Life.

We have learned how the cells individually live their limited existence in their close environment, absorbing food and oxygen from the adjacent blood, returning effete material to the blood and lymph channels, and the products of their activity, whether for future use within the body or as excrement, to other appropriate channels. Thus the liver sends part of its manufacture (e. g., transformed glycogen) into the blood of the hepatic veins and thence to the vena cava and right auricle, and another portion (bile) into the bile ducts and thence through the hepatic and common bile ducts to the duodenum. The kidney extracts from the blood in its glomeruli a part of its watery constituent, and from it, by the cells of its convoluted tubes, the special excrements peculiar to the urine, all coursing through the uriniferous tubules and conducting tubes to the renal pelvis, and thence along the ureter to the bladder.

Cell Defense.

We have also seen that there is ample provision for emergency action by the bodily cells. They are able to act under abnormal conditions so as to guard against disintegration, thus preserving the life of the individual. Our study has taught us that there are essentially but two kinds of tissues, designated higher and lower. We have noticed that when unduly excited or irritated, the higher tissues suffer and degenerate, and even die, while the lower tissues are spurred on to increased activity, proliferation and new formation. We have learned that granulation tissue, or scar tissue, is always the same, and results from cell proliferation, and that scar tissue always contracts, but more in some locations than in others.

Inflammatory Pain.

The preceding chapter has taught us that pain in these conditions is due to tension of and pressure upon, nerves. We know that the density and elasticity of tissues and organs differ, as does also the sensibility of various nerves. Putting both these facts together teaches us that pain in an inflamed part depends upon the sensibility of its nerves, the amount of swelling and the density and elasticity of the tissue itself. A structure as spongy, soft and elastic as the liver will yield to the outpouring of plasma, the growth of cells and dilatation of the vessels with minimum pain, whereas a firm and unyielding structure, as, for instance, bone or periosteum, does not yield, and every small addition to the effusion adds greatly to the pressure and tension, and hence also to the pain. For example, notice the comparatively slight pain in inflammation of the liver, immediately added to by manipulation because of increased pressure; and then observe the intense, severe and continuous pain in periostitis, as in an ordinary felon, in which the compression at once is so marked that the rhythmic contraction and expansion of the capillaries causes the intolerable throbbing pain that keeps the patient awake and drives him to the surgeon for aid. Another extreme illustration of the latter kind is the congestion so common about the root of a tooth, ending in a small pin-head abscess between the end of the tooth root and the apex of its alveolar socket.

Scar Ache.

Nerve ends are frequently surrounded by new cells, thus becoming incorporated in the resulting scar, during the subsequent contraction of which the nerve is so squeezed as to cause insufferable pain. This is a well known cause of persistent pain in stumps after amputation, for which the original scar is opened and the nerve end removed. We all recollect the "funny bone" at the elbow, a bump upon which causes tingling in the little finger and adjacent side of the hand and ring finger. The phenomenon is simply due to jarring of the ulnar nerve as it passes under the skin behind the internal condyle. A blow or pressure here squeezes the nerve, as the underlying bone does not yield, and results in a sensation of injury to the field of distribution of the nerve to the ulnar side of the hand and the little finger and adjacent side of the ring finger. This is referred sensation, and to it is due the peculiar fact that people with amputated limbs often distinctly feel the absent members. Legless people, notably in cold or wet weather, often complain of rheumatic pain in a foot, toe, or leg that was cut off years before. They are simply illustrations of referred sensation, due to irritation of the severed nerve ends.

Scar Constriction of Vessels.

The vessels passing through a cicatrix will be so squeezed during its contraction as to have their calibre much lessened or entirely obliterated. This fact is of the greatest importance in those organs through which blood must pass in large quantities in a given time to preserve the balance in the organism, as, for instance, in the liver and kidneys. Inflammation, consequent formation of cicatricial tissue, and subsequent contraction, markedly, and ofttimes dangerously, interfere with circulation.

The vascular dilatation, the exudation of plasma, and the cell proliferation that cause the tumefaction of inflammation, will, if it involve a whole organ, cause increase in its bulk. It therefore follows that the first stage (the active stage) of an inflammation of the lower tissues (connective tissues) of an organ always causes enlargement and more or less pain. For a given amount of exudation in any given organ, the resulting enlargement is dependent upon the density and resistance of its tissues. In other words, under similar circumstances the pain is dependent upon the density. The more unyielding the structure, the greater is the pressure exerted upon the nerves, and the more severely is it felt for a given amount of tumefaction. Thus the enlargement of the whole liver does not occasion nearly as much distress as the periostitis of a terminal phalanx where the slight swelling causing pain is due to periosteal thickening and the exudation of plasma and blood cells between the unyielding bone and this inelastic membrane. The student of anatomy will recall minute vessels that enter bone from its periosteum. If the exuded plasma in a case of felon is relatively large, it raises the periosteum from the bone enough to tear these bone nourishing vessels; the exudation and cell proliferation continuing, the dissection of the membrane from the bone goes on. The bone then dies because of lack of nourishment, at the same time the pain is excruciating because the structures between which the exudate occurs are very unyielding. This explains why a "bone felon" should be diagnosed early, so that an incision may be made through the normal skin and pulp of the finger end, down through the periosteum to the bone for the purpose of relieving tension by giving vent to the imprisoned accumulation, thus easing pain and saving the bone.

Inflammation of Higher Tissues.

Inflammation of the higher tissues (special cells), such as the cells of the liver and brain, results in their destruction. If the liver be affected, the organ shrinks, its functions are abridged, and the patient dies—of acute yellow atrophy. If the spinal cord be affected, loss of motion, or of sensation, results, as in acute anterior myelitis.

Nature's Amputations.

We have also learned that the suppurative process is nature's great method of cutting off parts of the body, and that the work is invariably done in the same way whether the structure be skin, connective tissue, muscle, or bone. Vascular dilatation and cell proliferation begin at once at the plane of separation between the dead and living structures, thus pushing off the dead part by liquefication of the plane of contact. This process is quickest in the soft tissues and slowest in the hardest structures, such as bones, tendons, ligaments and fasciae.

Two Parts of Tissues.

All organs are divisible into two parts, the essential and the non-essential, the former being the parenchyma,[1] composed of essential (special) cells, and the latter of the interstitial,[2] connective tissue, framework. If we now recall the fact that either of these parts of an organ may be more or less inflamed independent of the other, it is at once seen that inflammations of organs may be parenchymatous or interstitial, and that each of these may be acute or chronic interstitial or parenchymatous inflammations. We must also conclude that to have studied the inflammatory process of an ideal or diagrammatic tissue, is to have studied its general aspects in all structures. Minor changes in different tissues and locations are due to their altered conformation, function, relations and connections. Thus a given form of inflammation of the spinal cord will entail certain results, whereas the same changes in the liver will be followed by a far different train of effects. The former may lead to paralysis and the latter to interference of the portal circulation and disturbance of digestion. A few drops of blood exuded into the subcutaneous connective tissue would be harmless, and perhaps unnoticed, whereas the same amount effused into the respiratory centre of the medulla oblongata would surely cause immediate death.

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[1] From *παρά*—beside, and *ἐγχεῖν*—to pour in.

[2] From *inter*—between, and *cistere*—to place.

CHAPTER IX.

ILLUSTRATIVE APPLICATION OF THE FOREGOING GENERAL PRINCIPLES.

It may be claimed that anybody with a knowledge of the place and function of cells in health and disease, as has been outlined, should have no difficulty in describing any given inflammatory[1] process in any organ of the body, though he may never have studied its pathology. If there be added to this a knowledge of the function and gross anatomy of the organ and its connections, most of the local and general symptoms are readily divinable by logical induction. It thus becomes easily possible to foretell the remote effects and symptoms of inflammatory conditions of organs if the knowledge of anatomy, physiology[2] and histology[3] is accurate and applied logically with the foregoing general principles. In short, a thorough knowledge of minute and gross anatomy and physiology, together with a knowledge of the principles of cell pathology, ought to enable any one to reason out the pathologic changes that take place in an inflamed part, though its pathology has not yet been studied. The laws or principles previously laid down as governing all cell action are as immutable as that of gravitation. There are no known deviations from the rule. Given an organ or structure of which the histology is thoroughly understood by a given individual, and he can, with the facts and principles already laid down, give a reasonably good and true description of its various stages of either acute or chronic inflammation.

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[1] From *in*, and *flamma*—flame or fire; a common designation for all conditions in which nature attempts repair by increasing local circulation and cell proliferation, which is accompanied by pain and heat, and thus is likened to burning. The classic "four cardinal symptoms" used to be given as "heat, redness, pain, and swelling."

[2] From φυσις—nature, and λογος—discourse or description; the science of normal function.

[3] From ιστος—a web or tissue, and λογος—the science of microscopic structure.

Let us test this matter with an illustration. To do this properly, we must first select our organ, then study its histologic structure before we can rationally apply our principles. Let us select the liver.

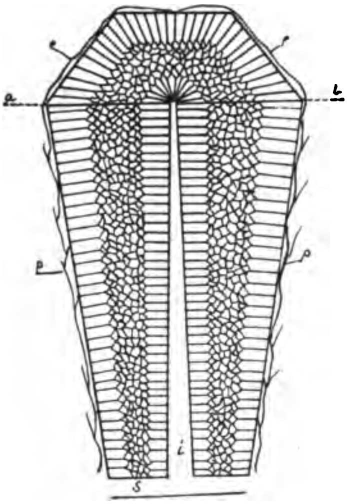
Liver Structure.

The chapter on organs taught us that an organ really consisted of its essential cells, i. e., that the liver is liver because it has liver cells. Remove these and it ceases to be liver, though it may have degenerated into a cancerous, amyloid, or fatty mass. But the liver differs from other organs in general appearance and in minute structure, and there is a reason for this. The liver cells have certain functions to perform, and for this purpose a particular arrangement is required. In the kidney another order is necessary because the work is different. In the industries we have parallel instances in a rolling mill on the one hand and a tannery on the other. Both are greatly different, because their requirements and functions are not alike.

We begin, then, with the fact that the liver is a mass of liver cells. These cells must be supported and held together, and that is accomplished by the connective tissue. They and their supporting framework must be nourished, and this is done by the blood through the arteries and capillaries. They must be drained of their common, or excretory, products, and this is done by veins and lymphatics. They must also be drained of their special products, and this is accomplished by the hepatic veins and the biliary ducts. The proper enervation of the whole cell mass is necessary, as is also the regulation of the supply of blood as to quantity and quality, and the maintenance of an equilibrium between ingestion, egestion, elaboration of new products and the rate at which they are required by the body at large; adjustments which are governed by the nerves from their proper centres. The liver is, therefore, composed of (1) essential cells, (2) a supporting framework, (3) afferent vessels to supply ingesta and work, (4) efferent vessels to abstract ingesta and secreta, (5) and an inciting, correlating and adjusting system of nerves.

Liver Architecture.

The architecture of the liver is upon a plan that economizes space and time. The cells are grouped in masses which form complete individual systems. These systems are individually connected, and may, and often do, serve the same conservative purpose that is secured in the construction of air-tight compartments in ships, i. e., the destruction of one does not interfere with the functions of the others, except, probably, to throw upon them a greater strain. These separate systems of living cells constitute so-called lobules. A vein extends through the centre of each lobule, appropriately called the central vein, and also very properly designated intra-lobular,[4]



Schematic Representation of a Liver Lobule, the part below the line *a*, *b*, being a longitudinal section, and that above, transversely through half of the lobule near its top. *p*, peri-lobular or inter-lobular veins, terminals of the portal system; *i*, intra-lobular or central vein, radical of the hepatic venous system; *s*, sub-lobular vein, the collector from the central veins. The diagram shows the inner and outer zones of straight vessels, and the intermediate plexus of finer vessels.

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[4] From *intra*—within.

vein because it is within the lobule, thus distinguishing it from those surrounding the lobule. These central veins (one in each lobule) merge with similar ones from adjacent lobules, thus forming a common efferent venous trunk that carries blood from the lobules, and these trunks are called sub-lobular veins. They unite to form the hepatic veins that empty into the vena cava as it crosses the liver immediately under the diaphragm and just before entering the right auricle. Thus the system of hepatic veins begins in the central veins, commencing in the middle of the top of each lobule, thence extending through its centre to its base, and ends in the vena cava.

The portal vein enters the liver at its transverse fissure, and rapidly subdivides in the substance of the organ till its final branches ramify around each lobule, and hence may be called peri-lobular veins, and, inasmuch as they lie between adjacent lobules, they are commonly known as inter-lobular[5] veins. The connection between the inter-lobular and central veins of the liver have an arrangement peculiar to this organ. The inter-lobular (peri-lobular) veins send relatively straight branches into the lobule toward its central veins for a short distance, thus constituting an outer or peripheral zone of straight vessels directed toward the centre. These then subdivide and inosculate, forming a capillary network that forms an intermediate venous capillary zone between the foregoing and another, central, one. The central zone comprises the portion of the lobule surrounding the central vein, and this is traversed by relatively straight vessels converging into the central veins from the capillary zone.

The Portal Vein and Its Peculiarity.

The portal venous system begins in the capillaries of the gastro-enteric[6] tract, excepting the rectum, and inclusive of the pancreas and spleen. From this extensive field, the veins coalesce to eventually form the great portal vein. Thus the portal system has the unique distinction of being the only system of veins to begin and end in capillaries,—from the gastro-enteric, splenic, and pancreatic capillaries to the capillory plexus within the hepatic lobules. The products of digestion must therefore pass through the intra-lobular plexus and veins of the liver before it can enter the heart and general circulation. The blood of the portal vein is rich in new pabulum that requires further elaboration. This takes place in its passage between the liver cells, while in transit from the periphery to the centre of the lobule.

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[5] From *inter*—between.

[6] Relating to the stomach and intestines.

The arterial and nerve supply of the liver accompanies the branches of the portal vein, and are therefore found between the lobules—in the interlobular spaces. The connective tissue framework of the liver is most abundant between the lobules, where it is most needed to hold them together and to support the vessels and nerves of the organ.

Application of General Principles.

Now let us apply a few general principles of pathology to this structure, and note the inductions that follow. We know that if fat is not consumed as quickly as it is brought to a tissue, it will accumulate. That which is brought to the liver comes from the portal veins fresh from the digestive tract, though much of it is taken away by the lacteals of the mesentery. It is introduced to the liver cells at the periphery of the lobules. Here, therefore, is where we would expect to find the first trace of fatty infiltration or degeneration of the liver. And that is where we do find it. Again, it is a well-established fact that amyloid[7] infiltration or degeneration begins in the capillaries. We would, therefore, expect to find this process make its appearance in the intermediate, capillary, zone of the lobule, where both the veins and arteries have their finest ramifications—and there is where we do find the first evidence of this process. And, again, we know that the heart is subject to many conditions that cause damming back of blood in the venae cavae. We would suppose that this back pressure would make itself felt in the hepatic and sublobular veins, and be through them transmitted along the central veins of the hepatic lobules, causing their distention, and a passive congestion [8] of the portion of each lobule around them. And we know further that long-continued passive congestions lead to discolorations due to the deposit of pigment from the sluggish or stagnant blood. We would, therefore, also expect to find pigmentation, a darkening of that portion of the lobule immediately around the central veins. And all of these conditions exist in such forms of heart disease as cause a damming back of blood in the venae cavae. The condition is known on this account as cardiac (heart) liver, and because of its appearance when cut across, a dark centre in each lobule, and its resemblance to a section of a nutmeg, it is called nutmeg liver.

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[7] From *α*, and *μυλη*—a mill; signifying made without a mill, and meaning wheaten starch; used to designate waxy-looking deposits in the tissue, a material that looks like boiled starch.

Thus we have beautifully illustrated the charms and the advantages of the induction method of study. Provided there is a proper groundwork to begin upon, the conclusions logically formed are positive and irrefutable. A few well-established principles in pathology, together with an accurate knowledge of the structure of the liver, enable us to unerringly conclude that the liver lobule is divisible into three pathologic zones, namely: an external (peripheral) of fatty changes, and intermediate (capillary) of amyloid alterations, and an inner (central) of venous stasis and pigmentation. Furthermore, we must conclude that these conditions may coexist—and they do.

Liver Inflammation.

Now let us take up liver inflammation (hepatitis).[9] The reader of these chapters is familiar with the process of cell proliferation, expansion, and subsequent contraction. Let us confine our attention to the few facts sought to be brought out in this chapter. In the earlier stages, of proliferation, there is expansion of the entire organ and a pushing apart of the hepatic lobules because of the accumulated cells and plasma between them. The organ is soft, it yields readily, and the pressure is relatively unimportant. There is slight soreness, and considerable tenderness (i. e., pain upon pressure). When proliferation has ceased, cicatrization begins. The new cells elongate, become united, become compactly arranged, and contract. Where before there was expansion, pushing the lobules apart, there is now contraction of their enveloping cicatrices. Each lobule lies within this steady, continued, increasing, merciless grasp of contraction that literally and actually at last squeezes the very life out of the individual. Cell after cell degenerates and dies for want of food and oxygen, so crowded does it find itself. Only the sturdiest ones resist. To the beginner, a view through the microscope of a field of liver tissue in the final state of this contraction compared with the normal tissue is a revelation of irresistible pitilessness. It is thus that the functions of the organ are gradually undermined and lessened. Food elaboration becomes less and less perfect with increasingly insufficient supply. The body at large, the health, suffers in proportion. But this is not all. The circulation of blood through the liver from the digestive tract, spleen, and pancreas is obstructed. There is resulting venous engorgement of the intestinal tract, with accompanying catarrh, defective digestion, insufficient generation of bile, and auto-poisoning[10] from enteric poisons formed in a crippled digestive tube. Hemorrhoids and abdominal dropsy follow. The heart labors harder to overcome the venous stasis in the gastro-intestinal tube. Respiration becomes impeded in consequence. Many secondary affections develop that the student and practitioner with a proper knowledge of anatomy, physiology, and histology can reason out. The sequence of secondary troubles is not the same in all cases, nor could it be expected, for the mode of life, the occupation, the kind of food, the age, and the conditions of various organs determine which parts are successively liable to attack because of their relative vulnerability.

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[8] From *con*—with, and *gestum*—to carry or accumulate; denoting an increased supply of blood.

[9] From ἡπατος—liver, and ιτης—bold, rash; used to signify inflammation.

Advantages of the Method.

Thus is shown the beautiful simplicity with which seemingly complicated conditions are unfolded, diagnosed.[11] The study of medicine begun in this manner is certain to be continued so. In this way it becomes fascinating, and its students become interested, curious, enamored, and faithful and diligent to the end. It becomes an ardent pleasure to teach them, and they go forth worthy representatives of a science and an art that knows no peer. The objection to present methods of instruction is that they do not teach the student to think, to reason. The inevitable result is that medicine must degenerate, or its advancement be retarded until a healthier mode of teaching is inaugurated.

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[10] From *αυτος*—self.

[11] From *δια*—through, and *γινωσκω*—I know.

Principles Applied to Other Organs.

If we now briefly apply our principles to some other organ, we note different results. In the kidney, amyloid changes begin in the glomeruli[12] as they are composed of the finer capillaries of the organ. Fatty changes begin in the capsule of Bowman surrounding the glomeruli and at the bases of the cells of the convoluted tube close to the basement membrane. In the interstitial[13] inflammation, the capsule of Bowman is thickened, and the connective tissue between the capsules and convoluted tube is increased. In the subsequent contraction the glomeruli are crowded together and squeezed, and the same applies to the tubules, which are compelled to shed their epithelial lining more or less completely according to the severity of the process in their locality. Again is the patient ultimately squeezed to death, but through his kidneys this time.

The same process may be applied to any other organ with substantially the same result. In the acute interstitial inflammations the entire process is quicker and marked by more local and general disturbance, necessarily. It may end in resolution and a complete cure, and it may end in suppuration and abscess. An operation may be required to give relief. The patient may die. Much depends upon the severity and extent of the attack, the health of the individual at the time, and the parts affected.

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[12] Diminutive of *glomus*—a ball; small capillary balls in the kidney.

[13] From *inter*—between, and *sistere*—to place; in interstices.

In the parenchymatous inflammations the result is destruction of the essential cell, and if this be general and in a vital organ the outcome necessarily is death. In the liver this follows within a few days (acute yellow atrophy). In the kidneys the result is the same under similar conditions, but the individual here has the advantage of having twin organs. One may rest to get well while the other does the work of both.

In the lung the interstitial inflàmmation masquerades under the confusing and meaningless designation of fibroid phthisis. The lung has no parenchyma in the same sense as the liver and brain, for it contains no higher cells. It is because of this that what might, for convenence, be classified as a parenchymatous disease (croupous pneumonitis) results in complete recovery. But it is useless to prolong the list. To do so is a valuable exercise for the reader, to whom it is earnestly recommended.

CHAPTER X.

NOMENCLATURE.

Lamentable, needless, confusion now exists in medical literature and text books because of no systematic nomenclature, though it must be admitted that one is gradually being evolved. Pending its complete evolution, however, which is not at all likely to occur during the lifetime of those now interested in the study of medicine, anything tending to that end must be acceptable. It is with a view to this end that this final chapter is added in the hope that it may lighten a portion of the burden of those who may look it over. Under existing conditions the poor student must learn the same thing over and over again under the mistaken notion that he is piling up new and necessary facts. Worse even than this is the fact that he never discovers his error, but goes plodding through life at the bedside with a disjointed notion of medicine and the resigned conclusion that the entire subject is an endless muddle after all. That is the end of progress, the death rattle of ambition, and the beginning of retrogression, of degeneration.

Under the system outlined in the preceding chapters, together with a systematic nomenclature, the student could in a short time, with much less effort and with positive pleasure, acquire so comprehensive a knowledge of the entire subject as would stamp him a master in fact as well as in name.

Value of Affixes.

The memorizing of affixes is a very valuable time-saver. There are not so many of them but that they could be memorized with little effort in the space of a week. It should be done with some system, and this would depend upon the mental peculiarity of the individual. I have arranged those which follow in what seemed to me a better order than the alphabetic because it would appeal more quickly to the understanding, and thereby reduce the tax upon the memory to that extent.

The following list includes those mostly in use and a few that, in my judgment, would better be used oftener than they are. The list is by no means complete, and was not unduly lengthened out of regard for the overworked minds of the students of to-day. Following is a list of prefixes:

DIRECTION.

Above—hyper.
super (also more).
supra.
Below—hypo.
infra.
sub.
Forward—ante.
antero.
ventrad (bellyward).
Before—pre.
pro.
Backward—dorsad.
postero.
Behind—post.
retro.

Sideward—laterad.
Headward—cephalad.
Tailward—caudad.
To—ad.
af.
From—ab.
ef.
a.
Out—ec.
ex.
Through or across—trans.
Return—re.
Right—dexter.
Left—sinister.

POSITION.

Within—en.
endo.
ento.
intra.
Without—ecto.
ex.
exo.
extra.
With—co.
com.

With—con.
sym.
syn.
Between—inter.
Against—anti.
Middle—meso.
Upon—ep.
Around—peri.
By or near—para.
Beyond or change—meta.

NUMBERS.

Half—demi.
hemi.
semi.
Many—multi.
poly.
One or single—mono.
uni.
Two or double—bi.
bis.
di.
dis.
duo.
Three or triplet—tri.

Four or quadruple—quadri.
tetra.
Five or quintuple—quin.
penta.
Six or sextuple—sex.
sexa.
Seven or sextuple—septua.
septa.
Eight or octuple—octa.
Ninth or nonuple—nona.
Tenth or decuple—deci.
deca.

QUALITY.

Hard—scleros.
scirrhus.
dura.
Soft—mollis.
True—vera.
False—pseudo.
New—neo.
Dissimilar—hetero.
Similar—homo (also often man)
White—leuco.
Black—melo.
melanas.
Large—macro.
Small—micro.
Straight—ortho.
Form—morpho.

MISCELLANEOUS.

Water—hydro.
hydra.
Man—homo (also often similar).
Heart—cardi.
Uterus—metra.
Marrow—myelo.
Self—auto.
Heat—thermo.
Mouth—stoma.
Pus—pyo.
Lungs or air—pneumo.
Bone—os.
osteo.
Difficulty—dys.
Muscle—myo.
Mucus—myx.
Vessel—vas.
Cartilage—chond.
Nerve tissue—neur.
Injury—trauma.
Measure—meter.
Negation—a-an.
Sensation—esthesia.
Pain—algia.
dynia.
Cutting—omy.
Cutting out—ectomy.
Blood—emia.
hemia.
Seam—raphe.
Fear—phobia.
Inflammation—itis.
Disease—path.
pathia.
pathos.
pathy.
To know—gnosis.
Formation—plasm.
plastic.
Tumor—oma.
cele.
A flow—rhea.
A hard flow—rhagia.
Thing to increase a secretion—agogue.
Like—oid.
Discourse—lògos.
Description—graphy.

Value of the Dictionary.

The student can, without suggestion, apply the information gleaned from these lists. The sooner he masters all of them the easier will he find his studies. Never fail to look up the meaning of a word you do not understand; should it be inconvenient to do so at once, do not trust to memory, but make a memorandum of it and be sure to look it up at the earliest opportunity. On this account a good pocket dictionary is a valuable adjunct to medical study; in fact, it is indispensable.

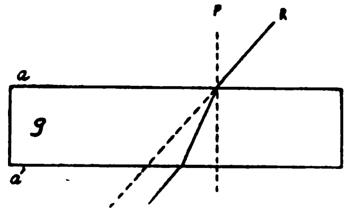
The reader must bear in mind the uses made of the following four words in these chapters, and he should interpret the language in harmony therewith. Thus by interstitial is meant the connective tissue framework of an organ; by parenchyma, its essential cellular portion; by acute, a process relatively short, sudden and severe; and by chronic, a process relatively long, gradual and without marked sudden disturbance.

In conclusion, the reader is advised to study any branch of medical inquiry in which he is engaged from every standpoint and with all the thoroughness of which he is capable. The more earnestly and thoroughly this is done, the pleasanter is the task, and the more readily is it remembered. There are, in fact, but few things that a student should strain to remember. It is much better for him to aspire to thoroughly understand, to become interested. Many students who complain bitterly of defective memories can read a long story with interest and then easily relate its incidents consecutively without having made any attempt to memorize it. They were simply interested and their understanding was given full play. The attempt to memorize lessons day after day is an injury to the mind and defeats its own object. Read, therefore, to understand rather than to remember, for enforced memory antagonizes a good understanding, though a thorough understanding is in itself the greatest aid to memory.

APPENDIX.

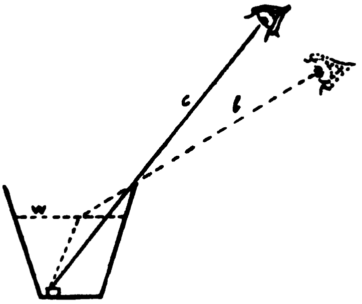
REFRACTION.

The microscope is a magnifying instrument in which advantage is taken of the bending of rays of light by glasses having curved surfaces. It is a well known law in physics that a ray of light is bent toward the perpendicular in entering a denser from a rarer medium, and, contrariwise, is bent from the perpendicular in entering a lighter from a denser medium. The subjoined figure usually serves to illustrate this point. The four-sided outline represents a section of a piece of glass through which the ray of light (R) is passing. P is the perpendicular passing through the glass at the point touched by the penetrating ray of light. As will be noticed in the diagram, the ray is bent toward the perpendicular upon entering the glass, and is again deflected from it to a similar extent upon again entering the air. The dotted line shows the direction the ray would have continued in had it not been deflected, and as it really seems to have continued to the observer at R. This bending of a ray of light, either to or from a perpendicular, according as it enters a denser or a lighter medium, is known as refraction.



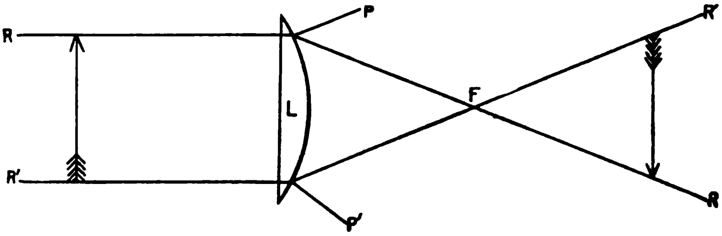
Showing the Course of a Ray of Light Through Air and Glass. *g*, **glass ;** *a* **and** *a'*, **air ; P, perpendicular ; R, ray of light.**

Almost every one is familiar with the experiment of placing a cent upon the bottom of a cup, and then moving the cup far enough away to just have the cent hidden by the cup's edge. While thus hidden from view, if water be poured in, the rays of light will gradually be bent until the cent is again visible, thus appearing to rise with the bottom of the cup, though the addition of the water has bent the ray of light so as to enable one to actually "see around the corner," or edge, of the cup. This is shown in the subjoined diagram.



Illustrating Refraction of Water in a Container. W, water level; *c*, the line showing direct vision and back of which the object cannot be seen except by the aid of refraction, which enables it to be viewed along the bent line *l*.

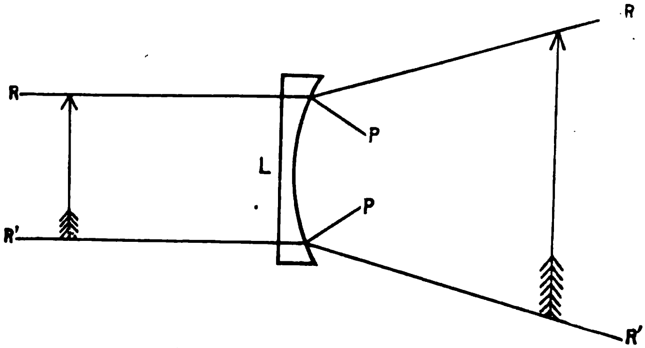
Advantage is taken of the refraction of light, to still further deceive the eye by rounding the surface of a glass disk so that the rays passing through it will come together at a single point, where they cross each other. This point of crossing is called the focus, and is illustrated by the following diagram: L represents a section of a glass disk flattened (plane) on one side and curved outwards (convex) upon the other, and is called a lens, and one of this form is known as plano-convex.



Showing Crossing and Reversing of Light Rays by Convex Lenses. L, lens; P and P', perpendiculars of its convex side at points of departure of rays R, R, and R' R'; F, the focus or point of crossing; the arrows indicating inversion of the figure.

R and R' represent rays of light entering the lens, which are bent toward each other upon leaving the glass, by being deflected away from the perpendiculars P and P' of the convex surface, eventually crossing at the point F, the focus, beyond which they again separate indefinitely in the direction they were traversing before meeting at the focus. It will also be observed that the ray R, which at first was uppermost, becomes the lowermost after leaving the focal, or crossing, point. The arrows serve to show, therefore, that an image transmitted through a lens and its focus necessarily becomes inverted.

If the lens was hollowed out (concave) instead of outwardly curved (convex), the rays would be dispersed, and the image would not be inverted, as is shown in the following diagram, in which the lettering has the same significance as in the preceding cut. A lens that is plane on one side and hollow (concave) on the other is called plano-concave.



Showing the Dispersive Effect of Concave Lenses. The lettering has the same significance as in the preceding illustration.

A lens that is concave on one side and convex on the other is called concavo-convex, or they may be biconcave or biconvex, the terms being self explanatory.

The further the object is seen beyond the focus through which it is cast, the larger does it seem, so that if far enough beyond this point, it becomes very much enlarged (magnified). But it becomes less distinct in proportion as it is magnified. Photographs are taken by means of lenses so arranged that they cast an inverted image of the sitter a short enough distance beyond the focus to get a distinct image and sufficient concentration of light to act promptly upon the chemicals used upon the prepared glass plate afterwards called the negative.

The indistinctness of the image when too far from the focus is called aberration, and the opposite condition of being very distinct is called definition. So that "good definition" means distinctness of outline and detail, while aberration signifies indistinctness, mistiness.

THE MICROSCOPE.

A microscope is simply a series of lenses so arranged as to greatly magnify objects. A tube is provided to hold them certain distances apart, and it is blackened upon the inside so as not to let in any other light except that which comes in at the end nearest the object viewed, the objective end. The tube and its lenses are supported by a firm and proportionately heavy base called the stand. Firmly connected with the stand is a flat shelf called the stage, having in its central part a large circular opening. Under this there is an adjustable mirror, usually double, with one side flat and the other concave. Between the mirror and the stage there is a circular disk attached, by its centre, close to the edge of the opening in the stage, and so arranged that it revolves and brings any part of its outer portion under the opening in the stage. This disk is known as the diaphragm, and has, around the outer portion of its surface, a graded succession of different sized openings, which, by revolving under the opening in the stage, regulate the amount of light passing through to the tube. In place of this, there may be a series of detachable diaphragms that may be set in the stage opening.

The tube is moved up and down by means of mill head screws working upon ratchets, or other devices, so that by turning in one way the tube is made to ascend, while a turn in the opposite direction brings it down. One of these acts quickly, and is called the coarse adjustment, and the other slowly, and is known as the fine adjustment.

The lenses at the lower end of the tube, i. e., close to the object, are called object lenses or objectives, while that at the upper end of the tube, i. e., at the eye of the observer, is known as the eye-piece or ocular. But below this is another lens, called the field glass, the purpose of which is to collect scattered rays of light, and concentrate them into the eye-piece, thus securing better definition. The eye-piece and the field glass are generally fixed in a short tube by themselves, which is slipped into the main tube.

While there is usually only one combination of eye-piece and field glass used, it is necessary to have at least two sets of objectives, one magnifying from 50 to 100 diameters, and called the low power, and another of from 300 to 400 diameters, and called high power. These lenses are detachable, screwing in and out of the tube, which is inconvenient. A device called a nose piece is attached to the lower end of the tube, and carries two or more sets of lenses, any one of which may, in a moment, be connected with the lower end of the tube by simply revolving all the objectives until the one desired is in place, and this is very convenient.

There are other accessories that serve to complicate the instrument without compensating benefit. Some of the finest microscopic work has been done with the simplest instruments. Of course, such work as counting blood corpuscles cannot be done without additional parts on an instrument as has been outlined. But the student is cautioned against fancy trappings, glitter, and so-called ingenious improvements. They are usually time and money wasters. But the mistake should not be made of buying an inferior instrument. A poor microscope is expensive at any price, in fact is expensive if donated, for it makes hard and unsatisfactory work, and this costs valuable time. When expertness has been attained in the use of this instrument, the owner becomes better qualified to select one of higher grade and price.

The student should recollect that his use of the microscope after graduation is very apt to be limited to urinary examinations, and for this purpose a good, simple, ordinary microscope of proper power and good construction is as serviceable as any that can be bought at any price. It is important that the stand be wide and heavy, so that the instrument may rest firmly wherever it is set. It may also finally be suggested that it is advisable, if one is not a practical microscopist, to obtain the aid of one who is in the selection of an instrument.

SLIDES AND COVER GLASSES.

Pieces of glass upon which to lay objects for examination under the objective are called slides, and they are usually three inches long and one inch wide. They may be bought already cut, with or without ground edges. If their cost is much of an object to the student, he can purchase a sheet of thin flawless glass for a few cents, and cut it up into strips of the usual size. A three-quarter inch disk of very thin glass is placed upon the object to protect it from the air, and also so that it may be hermetically sealed for preservation. This is appropriately called a cover glass, and may be round or square. Slides and cover glasses, particularly the latter because of their thinness, are difficult to clean on account of grease and other organic and sticky substances that cling to them, and especially the latter because of their delicacy, for they do not bear careless handling. If nitric acid is poured over them in a cup, goblet or beaker, all fat and other organic matter is destroyed. After this they are rinsed by running cold water over them, in which they may remain until needed.

OTHER ACCESSORIES.

A pair of fine sewing needles stuck in small pieces of wood, or other kind of material that will serve for a handle, are very useful for separating tissues for examination. This dissection with needles is called teasing.

There should also be one or two delicate forceps, with blades well separated when the jaws are in contact, so that if used to hold a cover glass and slide, they do not close upon the edges of the glass. There should also be a fine pointed pair of forceps for picking up delicate tissues and small objects. Long slender scissors with short blades and a very fine, sharp point are necessary. A straight and flat curved pair are desirable, but if only one is to be used, it had better be straight.

There should be several dishes large enough to hold slides and cover glasses, and permit of the floating of specimens upon slides without cramping for space. Several smaller dishes, such as good sized open salt cellars, are needed for straining and floating specimens.

Bibulous or blotting paper is very essential as it serves to quickly dry objects placed upon it, especially slides and cover glasses, and is used to absorb excessive moisture from the top of the slide when mounting an object.

Several bent copper spatulae are indispensable, as they enable one to easily and quickly lift out sections of tissues from the fluids in which they may be immersed.

Bottles containing reagents are essential parts of a microscopic outfit. Just what these should be it seems best to leave to the teacher of histology under whom the student is working. They include normal salt solution, sealing preparations, various staining liquids, glycerin, alcohol, chloroform, and nitric acid.

SOME USEFUL RULES.

Some rules to be observed follow, but they are by no means all that could be enumerated.

Never begin any work without knowing the entire proceeding from the beginning to the end, and only after having everything ready.

Always have, as far as possible, a uniform place for everything; one place for slides, another for cover glasses, one for implements of one kind and another for some other kind. This makes work easy and quick without effort or hurry to that end, and it yields neatness in results.

Label all specimens as soon as mounted, unless they are to be immediately destroyed.

Do not forget that there is dust floating in the air all the time, and therefore cover such work as needs it with a bell glass or other suitable substitute, glass being preferable because it does not hide from view though it thoroughly protects against dust. The microscope should be protected against dust. When the definition is poor, do not forget to look for dust upon the lenses.

When the lens is removed, its inner surface, i. e., the surface that faces inside the tube when it is in position, should always be placed downward, thus avoiding dust settlements, for it is easier to remove the dust from the superficial, outer, side of a lens than from its deeper set surface.

When the microscope tube is deprived of a lens at one end (with one end open), the unprotected end should be held down to avoid getting dust into the tube, and upon the inner lens surface at its other end.

Always place the microscope upon a firm support, one that has no perceptible shake, or it will not give satisfaction.

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